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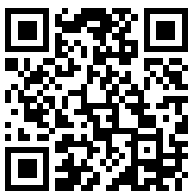

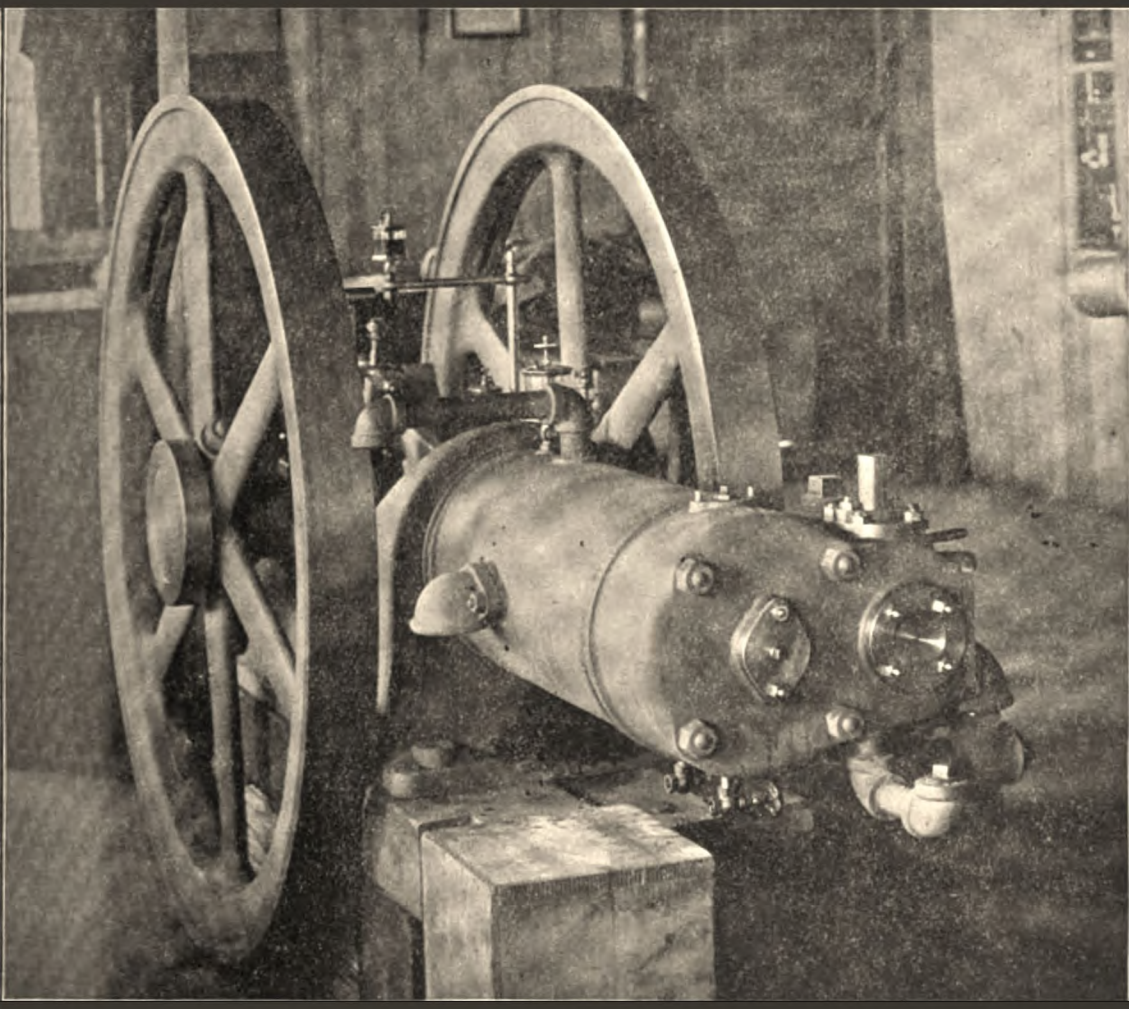

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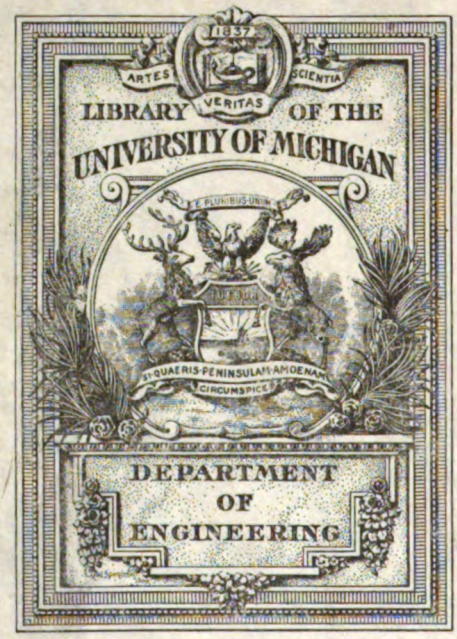

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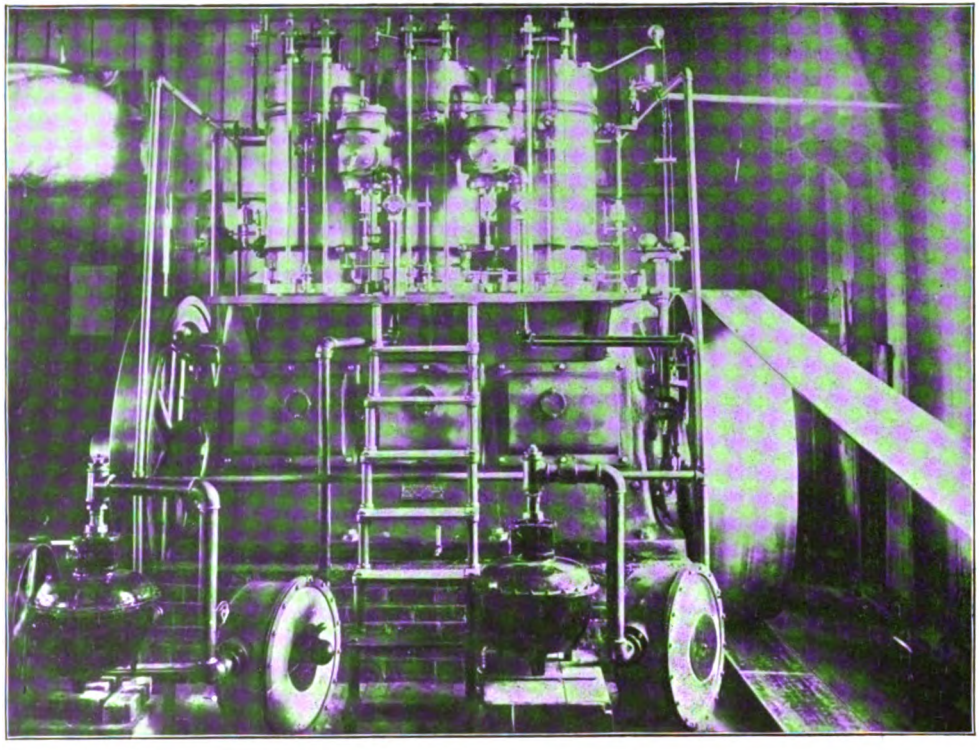

75 HORSE-POWER GAS ENGINE AT COUDERSPORT, PA.

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IN CORNELL UNIVERSITY.

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislature of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

THE INFLUENCE OF CLEARANCE AND COMPRESSION ON THE CONSUMPTION OF STEAM.*

H. DUBBEL.

Radinger, Hrabak, and others, in their works on steam-engine construction, recommend compression of the exhaust steam left in the cylinder and clearance, to the admission pressure, in order by this means, to remove the influence of the clearance upon the consumption of steam and the amount of work done. This widespread view rests upon Zeuner's deductions in Thermodynamics, which show that the indicator diagram of an engine with large clearance, but complete compression and similar expansion is equivalent to the diagram of an engine without clearance.

Prof. Boulvin, of Ghent, in a controversy over the experiments of Dwelshauvers-Déry, to be discussed later, has drawn a diagram with complete compression in the temperature entropy diagram, Fig. 1, by which he shows the influence of the cylinder walls. Line *ll* is the lower boundary curve with the abscissa $\frac{\tau}{a}$, where τ represents the known temperature-function, *sf* the adia-

* Translated from *Zeitschrift des Vereines deutscher Ingenieure.*

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batic expansion, $a\,m$ the line parallel to ll, of the complete compression in the diagram $a'\,m\,s\,f$, in which the heat exchange is not considered. Boulvin proceeds upon three following suppositions: the cylinder walls act toward the heat-movement as if they were affected with a certain sluggishness. As a result, during compression the walls do not begin to take up heat quickly until the temperature of the steam has exceeded considerably that of the walls. It is probable that, even at the end of complete compression, the temperature of the walls has not yet attained its highest value, so that condensation of the entering steam results, even during admission. In the diagram, $a'\,b\,c\,d$, which corre-

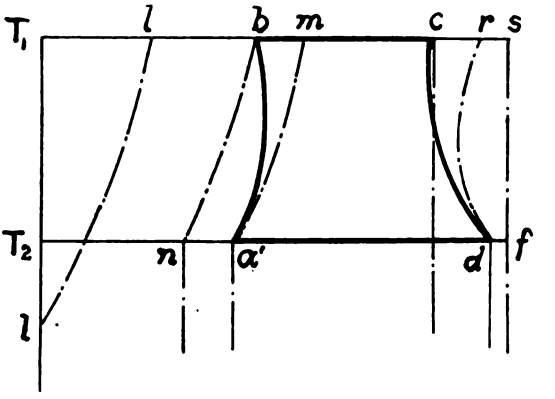

FIG. 1.

sponds with the steam diagram $b\,c$, is on this account smaller than $m\,s$. For the same reasons, the return of heat to the steam takes place only after a certain duration of expansion. If the abscissa of the triangle $a'\,b\,m$ is carried to the right of $c\,d$, the loss of heat, compared with the diagram without clearance, though with complete compression, appears upon an area corresponding in size to $r\,s\,f\,d$, whose determination must be the subject of a new investigation. The warming of the walls during compression at the higher temperature, and the heat given up to the steam at a lower temperature no longer balance and a net loss results.

The comparison of an engine diagram with that of one without clearance and with complete expansion, is without meaning. One perceives that the clearance V_0 Fig. 2 is filled with live steam at every stroke without yielding "full-pressure" work. The work of expansion of the clearance enters the diagram as

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the higher expansion line in the drawing. Fig. 3 shows the same diagram with the compression carried up to the admission pressure, by which the work $A\,C\,x$ is expended. In both cases the loss by expansion originates in the expansion work of the clearance, $H\,x\,y$. If the engine must show by Fig. 3, the same work as in Fig. 2, then the compression loss must be made good by increased admission, notice being taken of the fact that in such case $H\,x\,y$ will increase on account of the increased expansion pressure. If we make use of Poncelet's assumption that the expansion curve is a rectangular hyperbola, the losses are accounted for in Fig. 4 as follows:

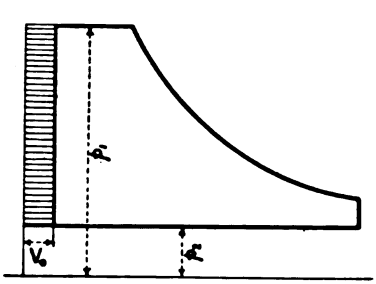

FIG. 2.

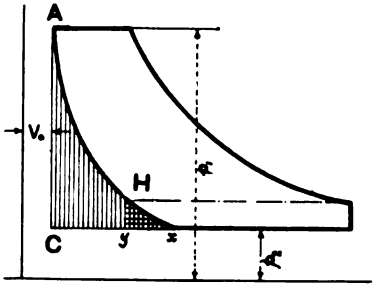

FIG. 3.

(1) Loss on full-pressure work, (corresponding with Fig. 2,) $= V_0\,(p_1 - p_2)$;

(2.) Loss through compression-work, (corresponding with Fig. 3,) $= V_0\,p_1\,log.\,\frac{p_1}{p_2} - V_0\left(\frac{p_1}{p_2} - 1\right)p_2 = V_0\left(p_1\,log.\,\frac{p_1}{p_2} - p_1 + p_2\right)$

Should the loss by compression be balanced by an additional admission, $V\,x$, then through this latter, work will be accomplished, of the value; $V_x\left(p_1 + p_1\,log.\,\frac{p_1}{p_2} - \frac{p_1}{p_2}\,p_2\right) = V_x\,p_1\,log.\,\frac{p_1}{p_2}$ which must be equal to the compression work. The relation of the value V_x to the value V_0 is then expressed by;

$$V_x = \frac{1}{n\,n}\,\frac{p_1\,log.\,\frac{p_1}{p_2} - p_1 + p_2}{p_1\,log.\,\frac{p_1}{p_2}}\,V_0$$

in which, by use of the factor $\frac{1}{n\,n}$, the double friction-loss is considered, which arises from the fact that the compression work is completed by the fly wheel.

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For a non-condensing engine with $p_1=8$, $p_2=1$, $N=0.85$, V_x is computed as 0.8 V_0. The insignificant advantage of high compression, computed from the diagram is thus more than outweighed.

Though large clearance does not always require large clearance surfaces, yet frequently they are so, as on valve and piston surfaces, and they occasion as a result of the increased initial condensation, a greater loss. The experiments of Callender and Nicholson have proved that 90% of the initial condensation is due to the clearance surfaces. The effect of the four separate steam passages in the Corliss type is not to be overrated in producing this waste.

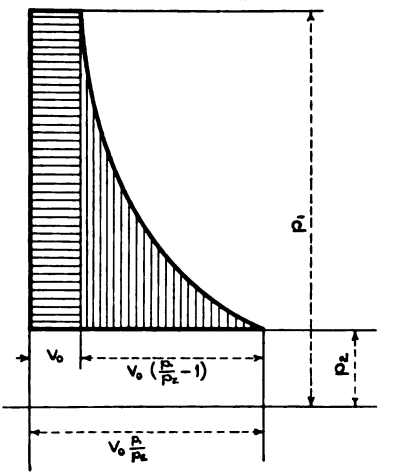

FIG. 4.

The volume of the clearance exercises an important influence upon the regulation. Its contents may, in spite of early cut-off, produce through its work of expansion, a mean indicated pressure, which exceeds that of the back pressure and the engine tends to run away; especially may this be the case with condensing engines.

(1.) TESTS OF DOERFEL.

Trial engine: simple Corliss, condensing, in the Radotin Cement factory. Diameter of cylinder, 554 mm. (21.8″). Stroke, 1250 mm. (49.2″). R.P.M. 54 to 58. Steam cylinders jacketed, cover not heated. Two boilers, each having about 72 sq. m. (755 sq. ft.) of heating surface. Pressure, between 5 and 6 atmospheres.

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The following cases were investigated :

High compression with cover jacketed, without " "	Greatest compression, forward, 47.44 per cent. back, 52.56 per cent.
Low compression with cover jacketed, without " "	Least compression, forward, 13.6 per cent. back, 13.8 per cent.

It was seen first of all that with high compression, the vacuum did not attain the value reached with low compression. At the beginning of compression, especially with early cut-off, a dimunition of the steam contents took place, which only enlarged with the increasing pressure through heat conveyance from the walls. A still higher rise of the compression line would be prevented by the steam giving up heat to the walls. The work demanded for the attainment of the greatest compression was greater than from the equation pv=constant; so that all calculations on that assumption are too favorable.

The extension of the vacuum to 0.2 kg. per sq. cm. (2.85 lbs. per sq. in.) corresponds with an hourly content of clearance of 9 kg. (19.84 lbs.) of steam. With low compression the steam saved amounts to 38 to 40 kg. (83.75 to 88.15 lbs.), or deducting the 9 kg., 29 to 31 kg. (63.9 to 68.3 lbs.). The effect without compression amounted to extra work at 56 r.p.m., of 2.9 H.P. This gave a saving of steam per I.H.P. of 10.3 to 11 kg. (22.7 to 24.25 lbs.).

With greater compression we obtain :

Final pressure of compression	2.8	3.3	3.6	atmos. abs.
Contents of clearance	105	122	133	kg.
Mean indicated pressure of compression,	.21	.24	0.3	kg.
Work of compression	15.2	17.4	21.7	I.H.P.
Steam saving per I.H.P. spent upon compression	6.3	6.5	5.7	kg.

With greater compression, the theoretical steam consumption per I.H.P. would be greater than the weight of steam saved.

Doerfel found as a particularly important result, that the *admission* loss with the greater compression was diminished. It even appeared that the condensation loss, with the high compression and without jacket was less than with low compression and with jacket ; which occasions 10 per cent. of the steam consumption, so that the advantage lies clearly on the side of the high compression.

It is, however, noteworthy that through the work of compression

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the theoretical consumption becomes so large that the total steam consumption with high compression is even yet more unfavorable than with small compression. The condensation losses were meanwhile not so much diminished as Doerfel expected, as they proved to be particularly dependent upon the moisture of the steam, and with high compression large quantities of water were found.

(2) TESTS OF DWELSHAUVERS-DÉRY.

(*A*) *Without Condensation.*

Trial engine; Steam engine of the Lüttich University. Cylinder diameter, 304.3 mm. (12″). Stroke 600 mm. (23.9″). Piston-rod diameter 49.7 mm. (1.96″). R.p.m. 45 to 60. Volume of clearance, 7.9 per cent. Area of clearance surfaces, 0.56345 sq.m. (6.07 sq. ft). Steam pressure, about 5.5 atmospheres absolute. Initial temperature about 200° C. Superheat, 45° C. The engine has flat slide valves with four separate steam passages.

In March, 1897, eight tests were made in which the engine worked with 10 per cent. and 20 per cent. compression. The admission, fixed at ten per cent., gave almost complete expansion. The unexpected results obtained in these trials, *i. e.*, the increase in the consumption of steam with higher compression, led to further investigations with 0 per cent. and 30 per cent. compression, the results of which confirmed those of the first tests.

Dwelshauvers-Déry next carried through a long program of research, of which three tests related to the running of the engine with 0 per cent., 30 per cent., and 40 per cent compression. The play of the piston was reduced at the top from 11 to 3 mm. (0.43 to 0.12″), so that the clearance was decreased from 7.9 per cent. to 6.6 per cent. yet the final compression, even with 40 per cent. compression, did not rise to the height of the admission pressure, as the condensation during compression increased so much that the compression curve showed the well known terminal hook.

In order to obtain greater final compression the test was repeated at 60 r. p. m.; yet only on one occasion did the compression pressure equal the admission pressure.

The results of these tests are given in Table I, and Figs. 4 and 5. From them it follows, in the first place, that the condensation increases with the compression, while in conformity with Doerfel's tests, the "initial" condensation diminishes, though slowly; so that the sum of $R_a + R_c$ (Fig. 5 and 6) increases.

As at 45 r. p. m. the steam consumption, according to the de-

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TABLE I.

Date of trial		7 Sept. 1897.	10 Sept. 1897.	16 Sept. 1897.	23 Sept. 1897.	22 Sept. 1897.	18 Sept. 1897.
Compression begins at	Per cent.	0	30	40	10	30	40
R. P. M.		45.41	45.37	44.82	61.68	60.86	61.73
Steam consumption per *I.H.P.* per hour	Kg.	16.196	19.512	25.435	14.910	18.529	24.470
Weight of mixture existing in clearance at beginning of compression, and participating in compression M_c	Kg.	0.001631	0.011099	0.014168	0 005161	0.011540	0.014349
Weight of steam in clearance space at end of compression M_3	Kg.	0.001631	0.0064	0.007193	0.00421	0.006814	0.007987
$M_c - M_3$	Kg.	0.000	0.004699	0.006975	0.000951	0.004726	0.006362
Heat transfer to the walls by condensation R_c	Heat units	0.000	2.8367	4.2102	0.6187	2.8940	3.9596
Heat collected in the cylinder with each piston-stroke Q	Heat units	18.3297	14.7060	13.5018	14.9232	13.0749	10.8891
Ratio of the quantity of heat transferred to the walls during compression, to the total quantity of heat $R_c : Q$		0.000	0.1929	0.3118	0.0412	0.2213	0.3636
Weight of mixture entering at each stroke M_a	Kg.	0.027223	0.021786	0.019984	0.02199	0.019328	0.016089
Weight of expanding mixture $M_c + M_a$	Kg.	0.028854	0.032885	0.034152	0.027318	0.030868	0.030438
Weight of steam at end of admission M_o	Kg.	0.019445	0.020554	0.020568	0.019329	0.020561	0.021091
Sum of the "before" and initial condensation $M_c + M_a - M_o$	Heat units	0.009409	0.012331	0.013584	0.007989	0.010307	0.009347
Initial condensation $(M_c + M_a - M_o) - (M_c - M_3)$	Heat units	0.009409	0.007632	0.006609	0.007038	0.005581	0.002985
Heat transferred to walls during initial condensation R_a	Heat units	5.5361	4.3455	3.7943	4.2102	3.2713	1.8949
Ratio of quantity of heat transferred to walls during admission, to the total quantity of heat $R_a : Q$		0.3020	0.2955	0.2810	0.2800	0.2502	0.1740
Heat transfer to the walls by condensation $R_c + R_a$	Heat units	5.5361	7.1822	8.0045	4.8289	6.1653	5.8545
Ratio of this heat transfer to total quantity of heat $(R_c + R_a) : Q$		0.3020	0.4884	0.5928	0.3212	0.4715	0.5377
Final value of heat lost through the walls $R_f = R_c + R_a + R_d$	Heat units	1.1831	2.4429	3.2632	0.7923	1.9755	1.8168
Ratio of this final heat loss to the total quantity of heat $R_f : Q$		0.0645	0.1661	0.2417	0.0527	0.1511	0.1668

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gree of compression, amounted to from 16.196 kg. to 25.435 kg. (35.35 to 56 lbs.) the loss amounts to $\frac{25.435-16.196}{16.196} =$ 57 per cent., at 60 r. p. m., the loss amounts to 64 per cent.

As to the final heat loss R_f, it is raised, by these trials at 45 r. p. m., from 6 per cent. to 17 per cent. and 24 per cent., with

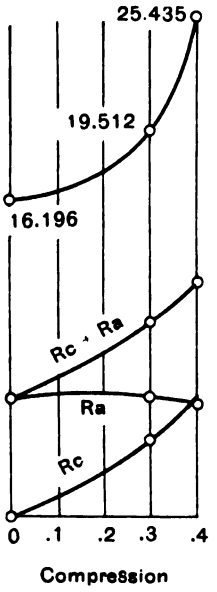

FIG. 5.

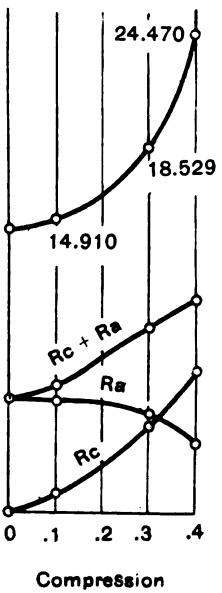

FIG. 6.

0 per cent., 30 per cent., and 40 per cent. compression. At 60 r. p. m. R_f increases from 5 per cent. to 15 per cent. and 17 per cent., with 10 per cent, 30 per cent. and 40 per cent compression.

(To be concluded in the November issue.)

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TEST OF A 75-HORSE-POWER GAS ENGINE AND PLANT.*

H. E. GEER, 1901, AND S. M. VAUCLAIN JR., 1902.

The Home Electric Light Company, of Coudersport, Pa., was incorporated about eight years ago to furnish arc and incandescent lighting for the town. The original installation consisted of a horizontal return-tube tubular boiler, 72 inches in diameter and 16 feet long, operated by using natural gas as a fuel, and a simple non-condensing McEwen automatic engine, with a 14-inch cylinder, and a 16 inch stroke, and using steam at about 100 pounds gauge. To this engine were belted the two main electrical machines; a Westinghouse alternator, generating 1100 volts at 1650 r.p.m., and rated at 1000 incandescent 55-volt lights; and a direct-current Brush arc machine, rated at 1500 volts and 9.6 amperes, at 1050 r.p.m. This machine furnished power for twenty-two 50-volt lamps. A third machine was the exciter for the alternator, giving 125 volts at 2100 r.p.m. Its belt was run on top of the arc machine belt.

About a year ago it was decided to equip the plant with gas engines, in order to make *direct* use of the gas, which abounds in this region, and also in order to compete commercially with natural gas lighting. The result was the placing of an order for two three-cylinder Walrath gas engines of 75 horse power each. These engines, as now erected, are both belted to a long jack-shaft, from which the three electric machines now derive their power, likewise by means of belts. The shaft is so equipped with friction clutches that either gas engine may be run alone, or both together, while any one or more of the electrical units may be run, at will. The supply of cooling water being of the utmost importance, three independent supplies are provided. The first is from the village mains. The second is by means of a Rumsey power pump, pumping water from a well, circulating it through the jackets, and then returning it to the well to cool. The third, which is the one ordinarily used, comes from a small reservoir owned by the Electric Light Company.

The two gas engines are identically alike. Each is a vertical

*An abstract of a thesis presented for the degree of Mechanical Engineer.

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three-cylinder 75-horse-power engine,* working on the Beau de Rochas cycle. The cylinders are mounted on an enclosed crank case or frame. The three cranks are set at 120°. The shaft, $5\frac{1}{8}$ inches in diameter, carries a heavy 5-foot fly-wheel at each end, and is supported by four main bearings. One fly-wheel on each engine has a broad (15″) thin rim cast on the regular rim, and is used as a belt-wheel. The cylinders have a diameter of 13 inches,

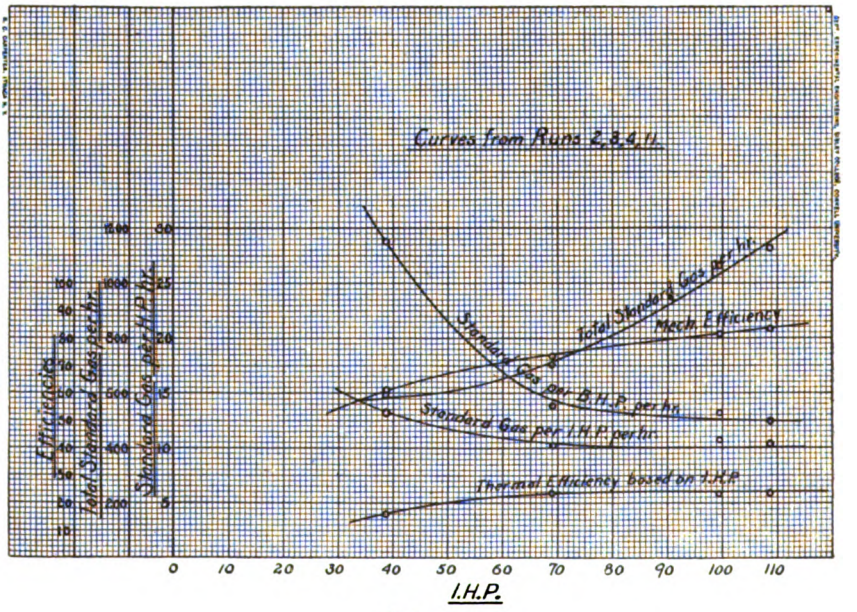

FIG. 1.

with a stroke of 14 inches. They are offset 3 inches from the centre-line of the crank-shaft; it being claimed by the builders that

(1). An explosion never occurs on the dead centre, thus doing away with the severe shock on the crank-shaft.

(2). The obliquity of the connecting-rod on the working stroke is reduced, thus reducing the lateral pressure on the trunk piston.

(3). During the exhaust period the motion of the piston is quicker, thus tending to clear out the exhaust gases more thoroughly.

A Holtzer-Cabot magneto-sparker, giving 10 volts at 2000 r.p.m., is belted to a pulley on an extension of the crank-shaft. To the same pulley can be belted, when needed, a small single-acting air compressor, for the purpose of charging the air tanks

* See Frontispiece.

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containing the supply of compressed air, which is used for starting the engine. The pressure carried in the tanks is about 180 pounds. Two of the engine cylinders receive their gas and air from common gas and air pipes through a single mixing chamber, while the third cylinder has separate pipes, and a separate mixing chamber, and is connected with the compressed air supply in such a manner as to utilize its pressure in starting the whole engine. When starting, the ignition spark is made by means of Edison-Lalande cells, which are cut out as soon as the magneto-sparker gets up to speed.

The tests made were of three general classes:—station runs, constant-load runs, and friction runs. Indicator cards were taken every ten minutes, except for three of the runs at constant-load, when the interval was shortened to five minutes. The following tables give the principal characteristics of the test.

Summary of Station runs:

	Run 1.	*Run 5.*
Duration in minutes	270	180
R.p.m.	253.3	253.2
Jacket water, pounds per hour	4026	3814
" " initial temperature	42.1	42
" " final temperature	142.3	156.1
Exhaust temperature	1024	1060
Gas per hour, cu. ft.	846	963
" temperature	69.5	69.6
" pressure in inches Hg.	0.88	0.824
Standard gas per hour	783	888.6
Indicated Horse-power, average	86.77	83.2
Developed Horse-power, average	68.56	68.88
Electrical Horse-power, average	45.1	47.17
Mechanical efficiency	78.7	79.05
Standard Gas:		
Per I.H.P., per hour	9.16	10.29
" D.H.P., per hour	11.7	13.14
" E.H P., per hour	17.71	18.95
Thermal efficiency, Engine	26.9	23.7
" " Plant	14	13.03

Summary of Constant-Load Runs:—

	Run 2.	*Run 3.*	*Run 4.*	*Run 11.*
Duration in minutes	60	60	80	90
R.p.m	258.4	253.2	247.3	241.8
Jacket water, pounds per hour	2882	2597	3947	3679
" " initial temperature	41	41	41	41
" " final temperature	156	145	143	146.3
Exhaust temperature	1027	1026	1042	1067

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Gas per hour, cu. ft.	656.3	778.1	1161.5	1233.2
" temperature	71.8	71.6	67.1	66.2
" pressure in inches, Hg.	0.77	0.8	0.85	0.75
Standard gas per hour	593.4	704.3	1063	1125.2
Indicated Horse-power	38.83	69 04	99.32	108.74
Developed Horse-power	20.62	50.83	81.11	90.53
Electrical Horse-power	15.47	21.18	61.46	68.93
Mechanical effiiciency	53.1	73.5	81.75	83.3
Standard Gas :				
Per I.H.P., per hour	15.27	10.2	10.7	10.35
" D.H.P., per hour	28.77	13.85	13.11	12.43
" E.H.P., per hour	38.33	33.27	17.3	16.33
Thermal efficiency, %	16	23.9	22.9	23.6

Summary of Friction Runs :—

Engine	18.21	H.P.
Jack Shaft	7.94	"
Alternator, field excited	6.82	"
Arc Machine	0.58	"

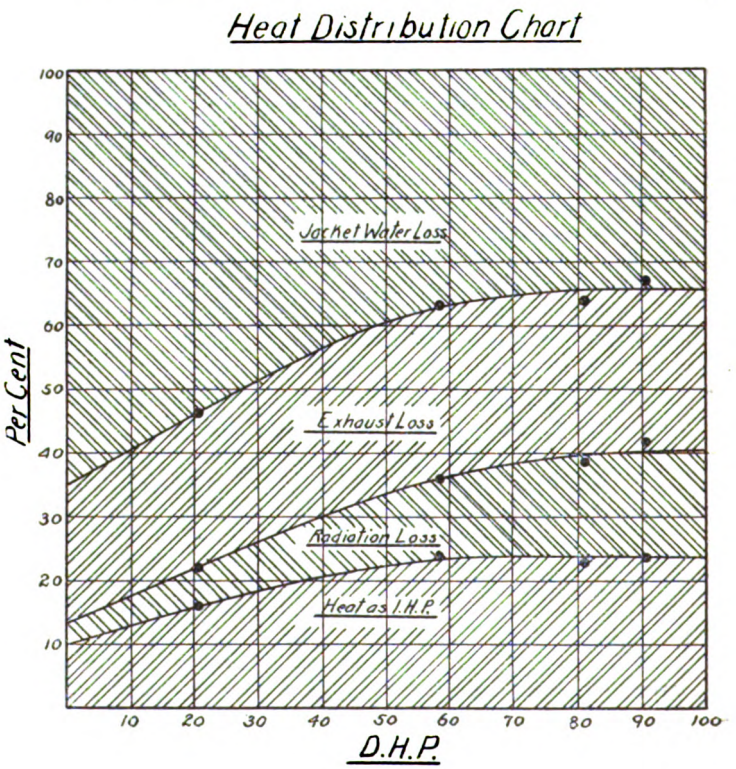

FIG. 2.

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An analysis of the gas used, showed a heating value of 1040.8 B.T.U., per cubic foot at 32° Fahrenheit, and atmospheric pressure. The ratio of gas to air used, was found to be as 1 to 12.15. The specific heat of the exhaust gases was determined as 0.256; the weight of one cubic foot of gas as 0.0455 pound. When mixed with air, the weight of one cubic foot, as fed to the engine, was 0.078 pound.

The distribution of heat for differing loads is shown by the accompanying diagram. It will be noted that the exhaust loss is nearly constant for all loads, and that the jacket-water loss is by far the largest for all loads, assuming extreme proportions as the load decreases.

THE EFFICIENCY OF THE BICYCLE RIDER AS A MACHINE.

R. C. CARPENTER.

The human body may be considered as a machine which possesses the power of transforming the energy supplied by food into mechanical work, and it is an interesting question as to how such transformation compares in efficiency with that of the steam or gas engine or other prime movers.

The most careful investigation which has yet been made in this line of research was conducted by Prof. W. O. Atwater of Wesleyan University, Middletown, Conn., and Prof H. C. Sherman of Columbia University, by very carefully determining the energy value of all the food supplied and rejected by two of the riders in the famous six day bicycle race held in Madison Square Garden, New York City. The writer of this article computed the mechanical work performed as nearly as possible from the data supplied. From the results of the computation the efficiency of the human system under the condition of severe and prolonged muscular work is approximately known. The results are interesting as they show an efficiency considerably in excess of any ever obtained by either steam or gas engine. The results are published in full in Bulletin No. 98, United States Department of Agriculture, office of experiment stations. This article gives a resumé of the experiments and the results obtained in computing the mechanical work performed.

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The six day bicycle race held in Madison Square Garden, New York, in December, 1898, represents one of the greatest achievements of muscular effort known. Thirty-one contestants entered the race and twelve finished. The observations were made upon three, one of whom withdrew early, while the others continued until the close of the race, holding the first and fourth places respectively. All of the participants had been trained for the race and two of them were experienced in contests of this sort. Their training was in the hands of Americans, so that it is thought that in dietary and most other habits they fairly represent American professional athletes. The two principal contestants were C. W. Miller and Frank Albert. Mr. C. W. Miller was a native of Germany, but had resided for six years in Chicago, previous to taking up athletics; he was 24 years old, 5 feet 5 inches high and weighed at the beginning of the race, 153 pounds 14 ounces. Mr. Miller covered a distance of 2007.4 miles in the six days, during which time he had an average sleeping period of one hour and 20 minutes per day. Mr. Frank Albert was born in Canada, but had lived in New York since boyhood. He was 28 years old, 5 feet 8 ½ inches high, and weighed at the beginning of the race 138 pounds 8 ounces. Mr. Albert rode 1822.6 miles in the six days and slept, on an average, one hour and thirty-five minutes per day. Miller lost about 4 pounds in weight on the first day of the race, during which time he rode 442 miles in 23 hours and 10 minutes; after this his weight remained nearly constant. Albert lost about two pounds on the first day, during which time he rode 402 miles in 22 hours and 40 minutes.

During the time of the tests a number of chemists were in attendance, and these gentlemen obtained samples of all the food supplied, from which at a later time analyses were made, thus enabling the energy supplied to be computed. A determination was also made of the energy lost in the discharges and rejections from the body. From this they were enabled to determine the efficiency of the digestion for each rider. The difference between income and outgo represents the total energy of the food.

The experiments did not accurately determine the energy due to the loss of weight of the riders. It was believed that the energy drawn from the body by Miller was equivalent to about 8 ounces of lean flesh per day, and that by Albert to about 6 ¼ ounces of lean flesh per day. There were, however, some inconsistences in the determination of the energy due to the loss of weight, and it was deemed advisable to neglect the computations for stored

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energy drawn from the body during the race, although this doubtless makes the efficiency as calculated much above that which actually existed. If all the loss of weight which occurred during the race, were to be considered as loss of fat, the energy drawn from the body would be very nearly equal that obtained from the food, in which case the efficiency would drop from 62 ½ per cent. in case of Miller to about 36 per cent. The actual efficiency of Miller as a machine, is somewhere between these two values, and is probably not under 40 per cent. nor over 50 per cent.

The following gives in full the results of the computations for mechanical work, as published in the Bulletin referred to.

No dynamometrical measurement was made of the mechanical work performed by the various riders who were the subjects of the investigations recorded in this bulletin ; consequently an exercise of judgment is required in order to determine the probable conditions which affected the resistances to be overcome.

The various external resistances can be discussed under two general heads :— (1) That of the air, and (2) that of the wheel.

AIR RESISTANCE.

Resistance of flat surfaces.—Authorities are not entirely in harmony as to the resistance produced by a body moving through the air with a definite velocity. Smeaton,* in 1750, published a table showing the relation between wind pressures and velocities which had been obtained by experimenting. This table corresponded to the formula $p = 0.005\ a\ v^2$, in which p equals the pressure produced per square foot, a the area exposed in square feet, and v the velocity in miles per hour. This formula was used extensively to aid in the design of large windmills, in the construction of which Smeaton was very expert. A. R. Wolff† deduces from theoretical considerations a table substantially like that given by Smeaton for a temperature of 45° F., but would indicate a pressure 10 per cent. greater at 0° F. and 10 per cent. less at 100° F, Allen Hazen‡ states that experiments with whirling arms, with plates exposed to direct wind and on locomotives, have shown that the formula $p = 0.0058\ a\ v^2$ is correct up to a velocity of 40 miles per hour. Professor Kernot, of Melbourne, in some recent experiments obtains $p = 0.005\ a\ v^2$, which agrees with Smeaton's formula. Various other authorities have

* Kent's Mechanical Engineer's Pocket Book, p. 492.

† The Windmill as a Prime Mover, p. 9.

‡ Engineering News, July 6, 1890.

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given different values for the wind pressure, probably because of some condition not noticed or corrected which affected the results. Thus, Marton* gives $p = 0.004\ av^2$; Whipple and Dies, $p = 0.0029\ av^2$; and Crosby† $p = 0.\ f\ a\ v$, in which f is a constant to be determined.

The weight of evidence would indicate that the wind pressure on plane bodies is very nearly equal to the amount represented by the formula, $p = 0.005\ a\ v^2$.

The pressure on a rounded body is considerably less than on a flat body; thus the pressure on a cylinder or cone is equal to one-half that of its diametrical planes.

Air resistance of riders.—The air resistance which a rider must overcome depends upon his body exposure. The data given show that Miller was 5 feet 4 inches in height, and had a waist measure of 34 inches, while Albert was 5 feet 8½ inches in height with a waist measure of 30 inches. One of these men being somewhat the taller and the other somewhat the broader, it seems quite probable that the exposure of each was about the same. This exposure would depend to a considerable extent upon the position in which they rode, it being noticeably smaller in the scorching position than when riding bolt upright. These men are reported to have ridden in a semi-upright position, as would probably be necessary because of the prolonged time of the race. The total exposure of a man of similar dimensions riding bolt upright has been found to be about 6½ square feet, in the semi-upright position 6 square feet, and in a scorching position a little over 5 square feet. The resistance on account of the rounded nature of the body is considered by the best authorities about equal to one-half of that of a plane of equal dimensions. From the author's best calculations the exposed surface in the semi-upright position would be equivalent to a plane of about 3 square feet.‡ At times it is doubtless equivalent to as much as 4 square feet, and during short intervals of scorching was doubtless much reduced. In some previous calculations the author con-

* Kent's Mechanical Engineer's Pocket Book, p. 492.

† Kent's Mechanical Engineer's Pocket Book, p. 493.

‡ According to unpublished results obtained by A. P. Bryant, at Middletown, Conn., the total exposure of a bicycle rider of about the build of Albert, when in different positions, as ascertained by measuring the shadow area, was as follows: When sitting bolt upright it was equal to 6.4 square feet; when sitting semi-upright, 5.9 square feet, and in the "scorching" position, 5.2 square feet.

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cluded that a small man riding for a short distance could bend his body into such a form that the resistance due to the air would not exceed 1.5 square feet of plane surface.* In the following calculations it has been assumed that the exposure of the riders was equivalent to 3 square feet of plane surface.

The work done in overcoming the wind resistance is equal to the pressure multiplied by the distance passed through in a given time. Thus if the pressure is expressed by the formula $p = 0.005\ a\ v^2$, the work done in foot pounds per minute, w, is expressed by the formula $w = 0.005\ a\ v^3\ d$. From this latter formula the following table of air resistance is constructed, showing the total amount of work done per minute with an equivalent exposure of 3 and of 4 square feet.

TABLE I.

TOTAL AIR RESISTANCE OVERCOME BY RIDERS AT DIFFERENT SPEEDS.

Speed per hour.	Wind pressure per square foot.	Wind pressure against rider.		Work done by rider per minute.	
		Exposure equivalent to 4 square feet.	Exposure equivalent to 3 square feet.	Exposure equivalent to 4 square feet.	Exposure equivalent to 3 square feet.
Miles.	*Pounds.*	*Pounds.*	*Pounds.*	*Ft. pounds.*	*Ft. pounds.*
5	0.125	0.5000	0.375	220	165
7½	.281	1.125	.843	743	562
10	.500	2.000	1.500	1,760	1,320
15	1.125	4.500	3.375	5,940	4,455
20	2.000	7.000	6.000	14,040	10,530
25	3.125	12.500	9.375	27,500	20,625
30	4.500	18.000	13.500	47,520	35,640

The data here used give only the average speed for each day, and the results are therefore computed from such information. As the wind resistance increases with the square of the speed, this necessarily makes some error, which may be considered, however, as compensated for by riding in a bent position so as to expose less surface when moving at a high rate of speed. It seems probable from the habits of most riders that such compensation may have occurred; if so, the results will not be greatly in error.

* See L. A. W. Bulletin, May, 1898, and Sibley Journal, Dec, 1899, p. 58.

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WHEEL RESISTANCE.

The author has made numerous experiments on various types of bicycles to determine the power required to overcome the various mechanical resistances. Quite an extended account of these tests was recently published* and the results need only be referred to in this article.

TABLE II.

FRICTION INVOLVED IN THE DRIVING OF VARIOUS CHAIN AND CHAINLESS BICYCLES AT A SPEED OF 15 MILES PER HOUR.

Total work per minute.	Mean pedal pressure. *a.*	Chain gear A.		Chain gear B and best chainless.		Chain gear C.		Chainless gear No. 1.		Chainless gear No. 2.	
		Friction per minute.	Efficiency.	Friction per minute.	Efficiency.	Friction per minute.	Efficiency.	Friction per minute.	Efficiency.	Friction per minute.	Efficiency.
Ft. lbs.	*Ft. lbs.*	*Ft. lbs.*	*Per ct.*	*Ft. lbs.*	*Per ct.*	*Ft. lbs.*	*Per ct.*	*Ft. lbs.*	*Per ct.*	*Ft. lbs.*	*Per ct.*
2,500	10.2	50	98.	150	94.0	250	90.0	208	91.6	783	67.5
5,000	20.4	57	98.8	241	95.8	332	94.3	288	94.25	813	83.8
7,500	30.6	64	99.2	271	96.4	414	94.5	367	95.1	842	88.8
10,000	40.8	71	99.3	331	96.7	496	95.1	469	95.3	893	91.0
12,500	51.0	78	99.4	392	96.9	578	95.4	549	95.6	923	92.6
15,000	61.2	86	99.4	453	97.0	660	95.6	640	95.7	965	93.6
17,500	71.4	93	99.5	514	97.1	742	95.7	723	95.85	997	94.4
20,000	81.6	100	99.5	575	97.2	825	95.8	812	95.94	1,037	94.8
25,000	102.2	107	99.6	636	97.3	907	96.2	875	96.5	1,040	95.9

a Mean pedal pressure for wheel with 6¾ inch crank and with 70⅝ gear.

* Sibley Journal, Nov. and Dec., 1899, pp. 58, 94.

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The friction of the driving mechanism, whether chain or bevel gear, absorbs much less mechanical force than that of the tire. The best grades of chain gear require less mechanical power to propel them than the bevel gear, but considering the great amount of force absorbed by the tire, this difference is not material.

The above table shows the work, in foot-pounds, required to overcome the internal (gear and bearing) friction of five grades of wheels, with different amounts of force applied to the pedals, and the corresponding percentage of efficiency of the wheels. The results are deduced from a series of experiments.

The following table shows in a similar manner the amount of work lost because of the friction of the tire on a single wheel when working under conditions similar to those under which the

TABLE III.

TIRE FRICTION OF REAR WHEEL AT A SPEED OF 15 MILES PER HOUR WITH DIFFERENT AMOUNTS OF TOTAL WORK.

Total work per minute.	Mean pedal pressure. *a.*	Very thin racing tire.		Heavy racing tire.		Light Road tire.		Ordinary road tire.	
		Friction per minute.	Efficiency.	Friction per minute.	Efficiency.	Friction per minute.	Efficiency.	Friction per minute.	Efficiency.
Ft. lbs.	*Ft. lbs.*	*Ft. lbs.*	*Per ct.*	*Ft. lbs.*	*Per ct.*	*Ft. lbs.*	*Per ct.*	*Ft. lbs.*	*Per ct.*
2,500	10.22	525	79.0	1,156	53.8	1,625	35 0	2,000	20.0
5,000	20.4	608	87.8	1,219	76.7	1,696	66.0	2,108	57.8
7,500	30.6	691	90.8	1,282	82.8	1,767	75.5	2,216	70.6
10,000	40.8	774	92.3	1,345	86.6	1,838	81.6	2,324	76.7
12,500	51.0	858	93.2	1,408	88.8	1,909	84.8	2,432	80.6
15,000	61.2	941	93.7	1,471	90.2	1,980	86.8	2,541	83.2
20,000	81.6	1,025	94.8	1,534	92.2	2,150	89.2	2,650	86.7
25,000	102.2	1,108	95.6	1,596	93.6	2,221	91.9	2,758	88.9

a Mean pedal pressure for wheel with crank 6¾ inches long and with 70½ gear.

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data in the preceding table were obtained. In estimating the total resistance of the bicycle, the results in this table should be doubled and added to the internal resistances as given in the preceding table.

The above results were obtained by deducting from the friction of the entire wheel, with tire, the friction of the same wheel without tire.

It is quite probable that the riders in the six-day races would select the best grades of bicycles and those which were propelled with the least expenditure of power. The author has found that riders are generally expert in selecting wheels which have the least friction. Hence it appears that it is fair to assume that the force required to propel the wheels would correspond to the lowest results in Table 3, and those next lowest in Table 2. This latter supposition is believed to be rather more probable, for the reason that the lowest results in Table 2 are to be considered as exceptional.

For a speed greater than 15 miles the resistance is increased in each case by an amount which was determined by the test and was equal to the amount given in the table multiplied by one-ninetieth of the increase inspeed. Experiments made in Sibley College laboratory show that for a difference in weight of 15 pounds the total resistance does not increase more than 2 per cent. As this correction is smaller than the probable error of computation, it has not been considered best to make use of it.

(*To be concluded in the November issne.*)

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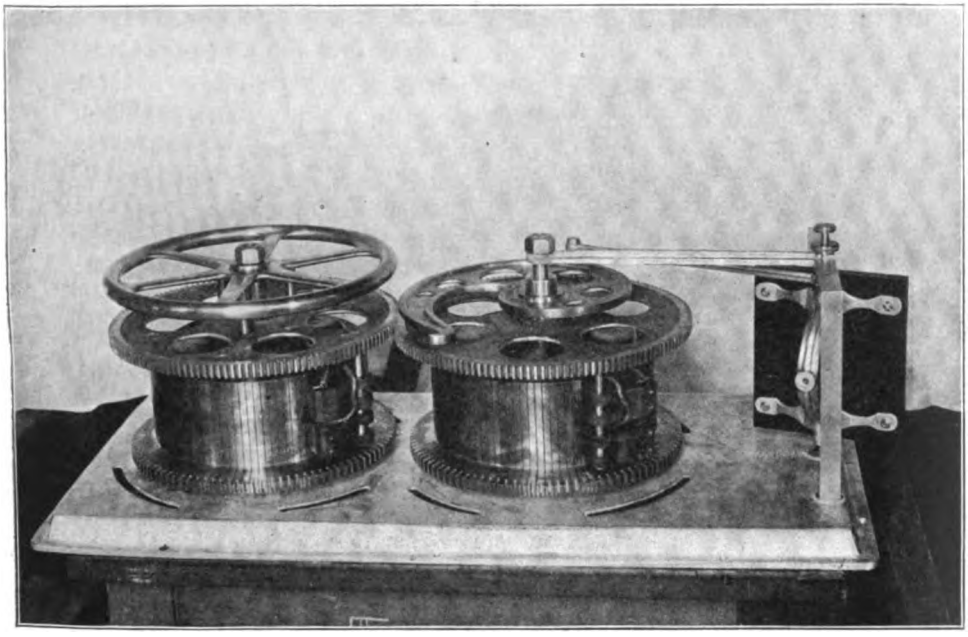

THE IMPULSE TRANSFORMER METHOD OF DEMONSTRATING THE WAVE FORM OF ALTERNATING CURRENTS.*

WILLIS H. CARRIER, 1901.

It is the purpose of this article to explain the above method, which was developed by Prof. Ryan in 1899,† and to describe the apparatus designed and constructed this year by Mr. G. W. Day, and the writer. .

This apparatus is designed to throw upon a screen a point of light which may be made to trace out automatically the exact form of the alternating current or alternating pressure wave plotted in rectangular coördinates. The speed of travel of the point is under the control of the operator. In all other respects the apparatus is entirely automatic. Its essential elements are a phase-changing transformer, an impulse transformer, an open circuit

* Abstract of a thesis presented for the degree of Mechanical Engineer.

† See article by Prof. Ryan in Proceedings of the American Inst. of Electrical Engineers.

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transformer (O.C.T. FIG. (2)), a specially constructed wattmeter with attached mirror to give the deflections, and the necessary mechanical apparatus to operate these elements in unison.

The function of the wattmeter is to indicate by its deflections the instantaneous values of the current or E.M.F. whose wave form is to be demonstrated ; that is, to give the ordinates of the curve. This wattmeter is of the Weston type, and consists essentially of a movable coil of fine wire with mirror attached, and suspended in the field between two stationary coils. In the stationary coils flows the current whose wave form is to be deter-

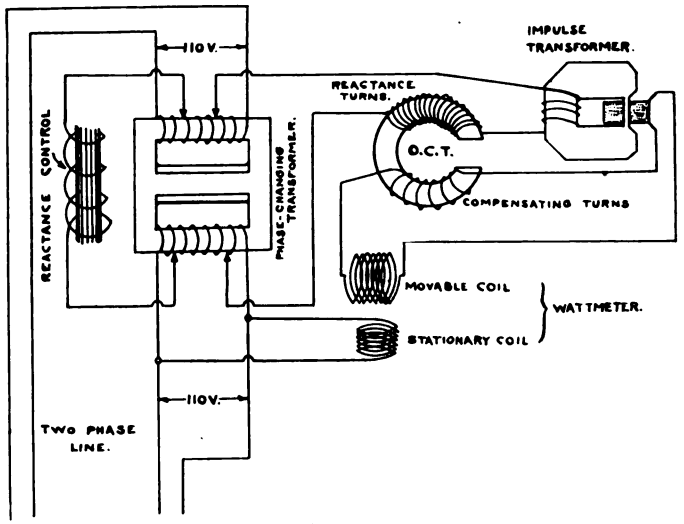

FIG. 2.

mined, while in the movable coil flows a current caused by an E.M.F. which has for its wave form a single narrow cusp as shown in FIG. (3). The method of producing the peculiar E.M.F. will be described later. When current is flowing in both coils there is at any instant a torque and consequent proportional deflection produced in the wattmeter, which according to Ohm's Law, is proportional to the product $i_1 i_2$ or $i_1 e_2$, where i_1, i_2 and e_2 are the instantaneous values. For all practical purposes the E.M.F. in the movable coil has but one value, e_2, and that comparatively instantaneous. Suppose both currents in synchronism. We will then have acting upon the suspended coil of the wattmeter a succession of equal momentary torques or impulses each of which is proportional to the product $e_2 i_1$, e_2 being the instantaneous value

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of the impulse E.M.F., i_1, the corresponding instantaneous value of the current at which the impulse E.M.F. occurs. These impulses are averaged by the inertia effect over the total time period to give a constant deflection so long as the relative phase position remains unchanged. Suppose, now, we vary at will the phase position of the impulse E.M.F., at the same time keeping its form and value constant. Our only variable in the product $e_1 i_1$ is the instantaneous value i_1 which depends upon the phase position.

Our resultant deflections will then vary directly as instantaneous values of the current, and we may in this way obtain all the instantaneous values of the current; that is, all the ordinates of the

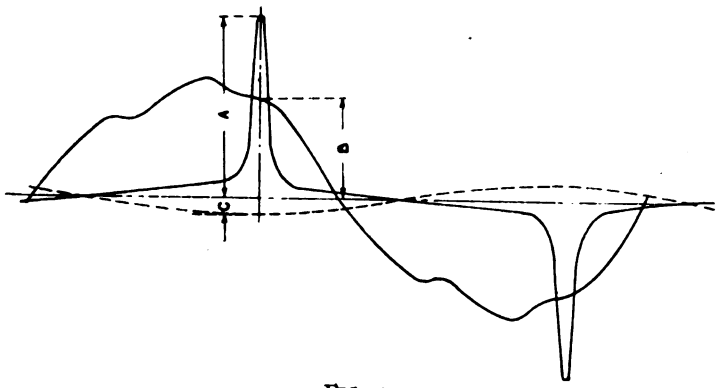

FIG. 3.

curve. Let the above deflections be shown by the vertical displacement of a point of light reflected upon a screen by the attached mirror. Suppose, also, by turning the wattmeter in the azimuth, that we are able to produce a horizontal linear displacement corresponding to the angle of phase displacement. Then we shall be able to make the point of light trace out the desired curve.

The problems which now require solution are first, the production of the proper form of impulse E.M.F. in unison with the given current or E.M.F.; second the shifting of its phase to any desired position relative to that of the given current or E.M.F. The third problem is the mechanical one of producing the proper horizontal displacement of the point of light.

For convenience of discussion let us grant that it is possible to produce the desired impulse wave from any ordinary synchronous alternation, It remains then to obtain this synchronous alternating E.M.F. whose phase may be changed any desired amount.

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This is accomplished by the phase-changing transformer. The necessity in this method of using a polyphase source will now become apparent. In this instance a two-phase source is employed, which may be obtained by three-phase two-phase transformation in case of a three-phase source. The principle of this transformer is as follows: If two E.M.F.'s in quadrature are placed in series in a circuit, they will together produce a resultant E.M.F. which is their vector sum, as shown in FIG. (4). Let E_1, E_2 be the values of the components and E_R the value of the resultant. It is evi-

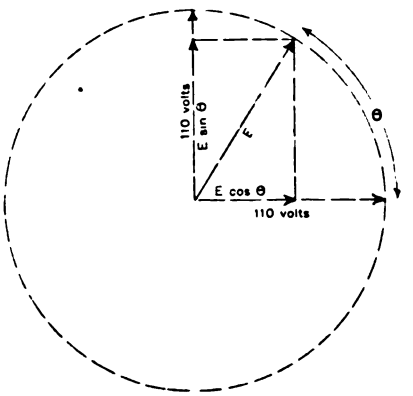

FIG. 4.

dent, if E_1 be varied from a maximum to zero and E_2 from zero to a maximum, so that $\sqrt{E_1^2 + E_2^2} = E_R =$ a const., that the phase of E_R will be rotated clockwise through the entire included quadrant. If, now, the connections of E_1 be reversed in the circuit, the rotation may be continued through the next quadrant by repeating the above operation in the reversed order. Next by reversing E_2 in the circuit we may rotate through the third quadrant, and finally reversing E_1 again E_R is brought back to its initial position, completing its change of phase through an entire cycle. The above is accomplished by placing in series the secondaries of two auto-converters to produce the desired steps, and having their phases in quadrature. The primary currents are taken directly from the wires of the apparatus being tested. The commutation necessary for the variation of the secondary on the "autos" and for the reversals is provided for by the two stationary commutators shown in the photograph of the apparatus, and which have each two sets of brushes placed diametrically

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opposite and rotated in unison by the engaging gear wheels and hand wheel attached. The entire process of commutation, the scheme of the connections, and the vector relations in the circuit may be readily understood by following out the diagram in FIG. (5). The coils in the center represent the "auto" coils, and their connections to the commutators are diagrammatically shown. The arrows show the directions of rotation of the brushes. The steps in commutation on the two transformers are such that the shift in the electrical phase of the resultant will correspond exactly to the angular shift of the brushes producing it.

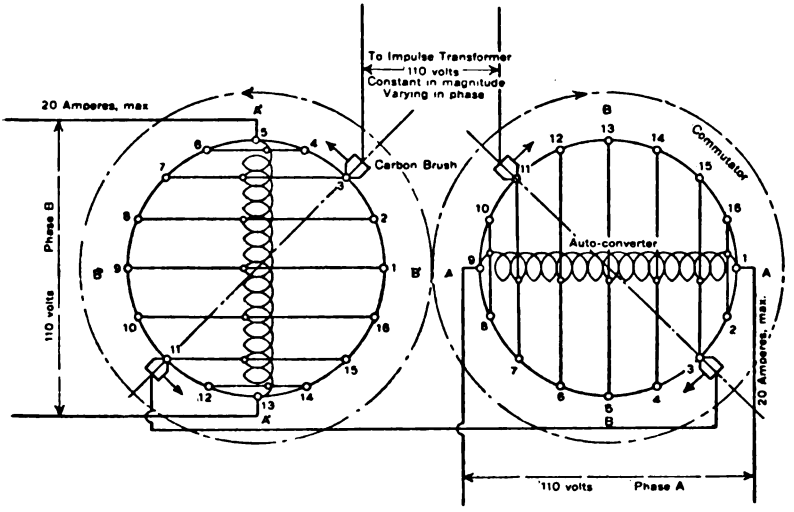

FIG. 5,

In series with the secondaries of this phase changing transformer is placed the primary of the impulse transformer, shown in the diagram of connections, Fig. (2). That part upon which the core is wound is comparatively massive and constitutes the principal portion of the magnetic circuit. The part upon which the secondary is wound is extremely short and narrow; its length is .395 in., and the ratio of its width to that of the large section is .112. It is then evident that a very small magneto-motive force will saturate this constricted portion. It will be remembered that the increase of flux with the increase of M.M.F. up to the point of saturation is exceedingly rapid while above this point relatively little increase occurs.

Hence we see that almost the entire variation and reversal of

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flux occurs during the relatively short period in which the exciting current passes through zero. By actual experiment this period is found by Prof. Ryan to be about 3 per cent. of the entire cycle. Therefore, since $E = \frac{dn}{dt}$, but little E.M.F. will be induced in the secondary during 97 per cent. of the cycle, while during the remaining 3 per cent. of the cycle a sudden impulse of relatively high E.M.F. is produced. The wave form thus produced and shown in Fig. (3), may be seen to have two components, one of which is the impulse wave desired, while the other, which may be termed the residue E.M.F., is practically a sine curve forming the base of the wave and lasting during the entire period of alternation. It is evident that the residue E.M.F. must be disposed of, since otherwise we would have a deflection of the wattmeter proportional to $ei + EI\cos\theta$ where e and i are instantaneous values, E and I the effective sine values and θ the angle of phase difference of I in the fixed coil and E in the movable coil of the wattmeter. Now note the open circuit transformer marked O.C.T. in Fig. (2). Its primary is in series with the primary of the impulse transformer, while it uses as a secondary, the compensating turns from the secondary of the impulse transformer. The direction and number of these compensating turns are so chosen that their E.M.F., shown in dotted lines in Fig. 3, will oppose, and exactly counterbalance the residue E.M.F., leaving only the impulse curve required. The deflection of the wattmeter will now be proportional to the product of the ordinates $(A - C) \times B$, Fig. (3) and therefore proportional to B, the instantaneous value of the current at any given point.

Inductive reactance control is used exclusively to limit the current in the primary of the impulse transformer. Since the impedance due to self induction is proportional to the periodicity, with sufficient self induction in the circuit, the third harmonic will be reduced three times as much as the fundamental and the fifth harmonic of the curve will practically disappear.

The Phase Indicating Mechanism. (See Fig. (1)).

The wattmeter, by means of a bracket, is pivoted upon a vertical axis passing through the center of the mirror. Extending from this bracket is a horizontal arm having a pin at its extremity which works on a cam. This cam is attached to the gear which shifts the brushes on the forward commutator and is so designed that the point of light reflected from the mirror will give a hori-

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zontal deflection upon the screen, which is proportional to the angular displacement of the brushes. The electrical phase displacement corresponds exactly to the angular displacement of the brushes, as will be seen from diagram Fig. (5); therefore the point of light will indicate by its positions in the horizontal plane the abscissae of the curve and by its vertical deflections the corresponding ordinates. The distance between the mirror and the screen and the direction of the source of light are immaterial. The point of light may be followed up on the screen with a crayon, thus marking the curve, or it may be made to trace its own path on a photographic film. Provision is made for the proper damping of the wattmeter, that the point may have a steady movement.

In conclusion it is proper to state that the credit for the origination of the above methods and devices is entirely due to Prof. H. J. Ryan.

THE SEVENTEENTH REGULAR REPORT OF THE DIRECTOR OF SIBLEY COLLEGE, 1900-1901.

Dr. Thurston's Report to the Board of Trustees forms an unusually complete and comprehensive exposition of the present and past status, and present and future needs of Sibley College. The different departments of the College are dealt with, one by one, and then general considerations affecting alike all the departments, are discussed. The Report is not intended for publication, but by kind permission of Dr. Thurston, we are enabled to give many of the main points covered by it.

"*The Graduate School of Marine Engineering* has continued its excellent work through the year and has found place for all its graduates; many of whom are already assuming positions of large responsibility and are exhibiting the most convincing proof of the advantages conferred upon young men of talent by such a course of professional instruction as is here offered students in Sibley College. Forty-one students have taken its courses and its full line of work has, at last, been put into action, including the special work of preparation in the junior and senior years of the undergraduate course of the College. The School has carried on its work quietly and efficiently under the direction of its

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able Principal and his talented assistant, and it has been crowded to its full capacity by appreciative students.

"It may be necessary to restrict its numbers hereafter unless special provision can be made for it outside the limits of the original Sibley College scheme of construction. The demand upon its little force has been excessive and too great for either comfort or maximum efficiency, as a great deal of individual instruction must be given. It is probable that we shall be compelled to decline to receive special students, our regular men having the first claim upon us; but while our restricted room and small force may make this necessary, it involves throwing out a class of peculiarly deserving men, a class for whom the founders had special sympathy and for whom they were particularly desirous of doing everything possible. It would be a source of great satisfaction to every friend of the School, the College and the University, could special endowment be secured for this School and thus these and other deserving men be fully cared for.

"The equipment of the School, so far as its regular courses of instruction are concerned, is very satisfactory and its work goes on smoothly and fruitfully. On the other hand, in the advanced work of research and of experimental investigation through the study of the action of wave and head resistances and other essential matters relating to further evolution of the science and the applied science of ship construction, much needs to be done, even though we are provided with the largest item of our needs and of expense in the great canal of the Hydraulic Laboratory of the College of Civil Engineering. With sufficient funds to enable us to perfect our outfit in this direction, very great opportunities will offer. As the Principal of the School has said: 'Possibilities are here presented which are unique as regards the educational and scientific aspect of the situation, and which will occasion the most serious regret if we are not able to realize in good measure the opportunities here offered.

"*The Graduate School of Railway Engineering* continues its steady and helpful progress in every direction of advance. Twenty students, including some of the ablest men in the College, are taking this work and are doing it as a rule finely. The course of instruction has been strengthened greatly by the requirement for its principal course of at least one summer's experience in the working of some railway, or private, locomotive shop. This has been a practice with the majority of the men in

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this school but it is now a requirement and no students who have not had such practical experience in the shop can complete this course and receive the certificate of its Head. This has been a common practice, not only with the students in this school but among the students of the College generally. It is now fixed as a part of this curriculum. The action thus taken has been cordially commended by all railroad men with whom we have taken counsel. The New York Railroad Club admits students to its membership who have complied with this stipulation, and the chief draftsman of a great railway who will not usually take on men fresh from college, offers to give positions to such of our men as have had this experience and at full wages for junior draftsmen.

"A Locomotive-testing plant is the first and greatest need of this school. It is well-provided with facilities for work on the road but it is not practicable to do all the needed work, either of instruction or of investigation, for the railway. There are many researches and there is much instruction which can only be satisfactorily carried on in the laboratory and with the most perfect and accurate of apparatus. Such a beginning of a complete equipment would cost about $50,000 including an inexpensive building to shelter it from the weather. There is here a very great opportunity to develop an important and useful department of investigation and experimental research and to invest a very considerable sum in a manner which will be certain to bring an exceptionally splendid return in promoting higher education in this field, in developing an important department of applied science and in adding to human knowledge in a most useful and and directly utilizable way.

"*The Department of Experimental Engineering* has made an excellent record, as is usual, during the college year, and reaches its end with its efficiency remarkably well sustained, its difficulties being considered, and with a large amount of work of fine quality to its credit. Its registration has been larger than ever before, with the exception of the two years of flood which compelled abnormal elevation of the entrance requirements for admission to the college, five years ago. Its list numbered 258, of whom 133 were juniors and 125 seniors. The coming year will see an extraordinary increase in this department, as the number expected to advance from the sophomore to the junior year and from the present junior to the coming senior class will be such as, with expected graduate students, to bring not less than thirty, and possibly as many as fifty, more men into the laboratory than are

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now instructed there, making a total of between 310 and 325 in all grades. As the laboratory is already filled to its full capacity and the existing staff is already overworked, serious problems will arise with the opening of the coming academic year. It may be, of course, possible to add to the number of instructors, provided men can be found competent and at the same time willing to accept our inadequate compensation ; but what we shall be able to do in the direction of accommodating larger sections in our limited space can only be told after trial. An efficient and experienced assistant has long been needed in this department, and it will perhaps be found practicable to find the needed aid ; but it is more than possible that we shall be compelled to cut off a part of the instruction now offered.

"The department is greatly in need of quarters adapted to its purpose and of at least double the present extent. It is now housed in the shop-extension of ten years ago, and it has neither sufficient nor proper space in which to conduct its exceedingly important operations. For its purposes, special constructions and forms of building precisely designed to meet its needs should be provided. It has performed so much and such splendid work that it would only be a justice to a deserving and at present hoppled department to give it the finest structure of the class that man can build. Plans are already prepared in the rough and details could be promptly worked out should this accommodation be proposed. The cost would be moderate for so important and fruitful a department. It should be given all the space and as large a staff as it can profitably avail itself of.

"*The Department of Electrical Engineering* has continued its very admirable work with a large student-body and its output is well-sustaining its reputation and that of the University among business men. The number of its alumni who have engaged in teaching is very considerable and it is a pleasure to be able to state that they are taking an important place in the education of the country in this field. A number of them are coming to be well-known, professionally, through their writings and their work in research and, though still young, some are already distinguished. The course of instruction is steadily evolving and taking more perfect and efficient shape and the able men who have it in charge are gradually putting into complete and permanent form so much of the course as can be condensed into a text-book, given in tabular form or presented on lantern slides.

"A text-book for the junior class is well in hand and its authors,

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Messrs. Ryan, Norris and Hoxie, have already written and re-written the book, more than once informally printing it, to make sure of its correctness in form and matter before publication. A text for the senior class will follow and, it is hoped, still later, time may be found to prepare one for the classes of mechanical engineers which are not in the special courses in this department. Formal descriptions and directions relating to tests of complete power-plants will be included in the experimental division of these works.

"*The Department of Machine Design* has had the advantage of complete re-establishment of its work on its normal basis; its Head having returned to the University after a year of absence on leave, during which he obtained some opportunities to become practically familiar with very extensive and important lines of practice, especially in the mining regions of the West. This department is happily so organized, at present, that it is presumably safe against the dangers which menace other departments, in case of absence by illness or resignation of the head. It is well "relayed". It has, however, experienced the usual difficulties in filling vacancies on its staff on account of the facts that we are able to offer but about one-half as large compensation as is given in business to men of similar capacity, that we need men, not only of excellent capacity but having peculiar and rare talent, and that we demand, combined with this special fitness by natural capacity and of a genius for the work to be done, a satisfactory combination of practical experiences with scholastic prepation, professional training and scientific methods of work. The combination is essential to success and is very difficult to find; then, when found, it is not always easy to secure the desired appointee, who often prefers business to teaching and always realizes that his services will be probably much more justly compensated in business. *

"*The Department of Mechanic Arts* has been greatly overcrowded during the past year and is at its limit of capacity for good work. It has only been saved most serious embarrassment through the fact that a large number of students have chosen to take their shopwork in the vacations, thus relieving the department while themselves securing either additional time for their term-work or

* Since the report was submitted, Assistant Professor Kimball has resigned, to accept a better paying position in business, and the hazards attending inadequate salaries are once more illustrated.

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providing opportunity for the prosecution of elective studies in other divisions of the University. The number of students registered was, in 1900–1, about two hundred in the wood-shop, one hundred in the foundry, and the same in the blacksmith shop, and two hundred in the machine shop. The total registered in term-time was six hundred and six in the first and five hundred and twenty-eight in the second term, when many seniors, having finished their work in this department, withdrew. One hundred and five students worked in the shops last summer vacation. A large number of others, also, worked during the whole vacation in various locomotive and railroad shops in all parts of the country.

"*The Department of Industrial Drawing and Art* has done admirable work during the year and its special developments have been promoted effectively by its talented and earnest teachers.

"In addition to the class-work in course, the work of this department in electives is important. The class in modelling has done some fine work, as usual, and the advanced class in freehand drawing has been increased considerably by admission of students from the College of Architecture. More time will be given to this advanced work, including modelling, hereafter and, with the rearrangements compelled by overcrowding and by the necessity of reconstruction of the division of mechanical drawing, it is found possible to work this part of the plan into the two-term system.

"*Graduate work* is each year becoming more general in engineering and, in this respect, our schools promise to excel those of the other professional classes. The advanced work of the graduate in engineering is constantly absorbing more and more of the work offered in the schools of law, of economics and of related technical departments. Steady progress is still observed in all directions and the engineering school of the twentieth century seems likely to take on generally the character of the engineering schools of to-day at Cornell and their advancement is evidently to be along the lines which have been pursued here for many years past and which have proved, meantime, to be wonderfully successful in preparing the young engineer for his work in life and for the profitable employment of his later years of success in broader and more cultured departments, developing more generally the gentleman and the scholar as well as the professional business man.

"*The Teaching Staff*, in the grades of professor and assistant professor, in Sibley College, has not yet been made as extensive as, in the interests of highest efficiency is desirable; nor does it com-

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pare favorably in this respect with other divisions of the University. In the determination of the question regarding assignments of new appointments called for in large excess by the various colleges of the University, this point should be kept in sight, as affording some approximate guage of the relative number of appointments and promotions to be allowed. The following table exhibits this comparison very strikingly and it may assist in throwing into relief the fact that equitable and customary proportions of officers to students are not yet nearly reached in the case of Sibley College. The hardly less important consideration that the Director has been extremely modest in his calls upon the Board for such aid in his work of making the institution a well-officered and consequently efficient section of the University is equally well shown.

RATIOS OF OFFICERS TO STUDENTS.

COLLEGE.	PROFESSORS.	ASS'T. PROFS.	STUDENTS.	RATIOS.		
1	2	3	4	4 : 2	4 : 3	4 :(2+3)
Vet. Medicine	4	3	41	10	14	6
Medicine	29	1	336	12	336	11
Forestry	1	2	22	22	11	7
Agriculture	4	2	91	23	45	15
Law	6	0	176	30	—	30
Civil Engineering	5	1	179	36	179	30
Architecture	1	3	50	50	17	12
Academic	30	21	744	25	36	15
University	87	36	2458	29	66	20
Sibley College	7	3	654	93	218	65

In connection with the above, it may be remarked, that a delegation from the University of Birmingham (England), on visiting this country in November, 1899, for the purpose of making a study of our great technical schools, incorporated in its report tables showing the students and instructing staff in Sibley College and in the Massachusetts Institute of Technology. These tables elaborated and rearranged as to form, give the following data :—

	Sibley.	*Technology.*	*Sibley.*	*Technology.*
Students	471	1171	*per 1000 students.*	
Professors	6	23	13	20
Assistant Professors	3	30	6	26
Both	**9**	**53**	**19**	**46**
Instructors	12	50	25	43
Assistants	12	33	25	28
Total Staff	**33**	**136**	**69**	**117**

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"The following tabular statement gives a measure of the extent to which the alumni of Sibley College are taking advantage of the opportunities which are coming to them as a result of their good fortune in securing a professional training.

ALUMNI OF SIBLEY COLLEGE.

Occupation.	*Number.*	*Per Ct.*
Agents and commercial	43	5.42
Apprentices	18	2.27
Designers and draughtsmen	75	9.45
Educators	81	10.20
Editors and writers	6	0.76
Engineers (independent of responsible chiefs)	254	31.98
Foremen and inspectors	24	3.02
Machinists	4	0.50
Managers and superintendents	94	11.84
Miscellaneous	107	14.11
Master Mechanics	4	0.50
Manufacturers	23	2.90
Patent lawyers	2	0.25
Presidents	15	1.89
Vice-Presidents	9	1.13
Steel-makers	8	1.01
Treasurers	9	1.13
U. S. Patent Office	7	0.88
U. S. Revenue Service	6	0.76
Total reporting to date	794	100.00
Not heard from at date	294	
Deceased	47	
Total alumni to date	1135	

"Nearly ninety-five per cent. of the above have been graduated since 1885 and are presumably not above 35 or 37 years of age; about three-fourths have been sent out within ten years and are less than 30 or 32; one half have been given their diplomas within about five years and are 25 to 28 years of age.

"The equipment of the College in all of its departments is constantly improving, largely if not mainly, each year, through the liberality of its friends. The great central 'dome' to be erected this year by Mr. Sibley is our finest accession and it will give us a noble pile, architectually, and provide long-needed facilities for instruction of our growing student body. The splendid front overlooking the campus will well symbolize the noble work going on behind it as well as the fine generosity and public spirit which has stimulated and sustained its builder and the Founder of the

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college. It will give us an imposing auditorium, a spacious and convenient fire-proof museum and several thousand square feet of additional working space. It greatly relieves the existing pressure.

"The gift by the Westinghouse companies at the suggestion of our Trustee, Mr. Kerr, of a large steam-turbine with its attached dynamo was noted a year ago; although it was received too late in the year to permit extended description. Since that date, we have received a high-pressure steam-boiler from the Babcock & Wilcox Co., built of steel and designed to carry 225 pounds working pressure. It is actually now adjusted at 175, that being the pressure intended to be employed on our experimental engines. It is also fitted with a superheater, the most important of all accessories for promotion of economy in the use of steam by steam-engines. This valuable and useful addition to our boiler-plant makes us for the time comparatively safe against deficiency of steam-power for any ordinary demand. This boiler, with its fittings is worth about $3500 and the new steam-plant as a whole may be inventoried at $10,000. The Roberts Co., has also sent us a small boiler for high-pressure work in our laboratory and this may be driven up to forty or fifty horse-power without risk and worked at any pressure that we can in any ordinary way employ and without danger. It represents about $1000 added to our inventory. Many gas-engines, oil-engines and smaller contributions to our equipment and facilities for instruction or research have been made and our outfit grows faster by such help from our friends than by purchase.

"On the regular supplies of the year, we probably secure more aid in the form of discounts than in gifts. The two methods of promotion of our work by our outside friends together constitute a very large contribution to the work, the extension and its development. The gifts during the present year, apart from the grand contribution of Mr. Sibley, amount to probably not far from $12,000 and, that included, to $85,000, or more.

"The magnificent opportunities of the university, and especially of Sibley College and allied departments of applied science, are plainly quite unrealized by even those who should be most competent to understand their bearings upon the social and business interests of the state. That they are not comprehended and realized by the average law-giver, or even by the occasional statesman, is indicated by the comparative neglect of the Land-Grant college of the state of New York by its own law-

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givers; not even the introduction of bills looking toward attempted legislation in promotion of these interests being recorded in the journals of the state legislature. Compulsory education of 600 New York state scholars without tuition fees, involving a burden of about $180,000 *per annum*, net, of which about one-third is a charge against Sibley College, appropriations, contrasts strangely with the appropriation by the new state of Washington, for its Land Grant College, of about $300,000 in the last year, of the special appropriation by Indiana of $100,000 for a single building for its state college, of $200,000 for a science building by the province of Ontario, Canada, and of continuous appropriations of definite and liberal special taxes by nearly all the western states for the same objects.

"If it is desired to make this institution 'second to none,' it is entirely practicable—given the needed material support and backing. With the position now held before the world, with its methods approved and followed almost universally, with its output already recognized and approved in every part of the country, and especially with a plan and scheme of development which permits an evolution only limited by the materially possible or practically desirable, there is no reason in the nature of things why we should not illustrate here, in Cornell University, most admirably and profitably that "complete and perfect education" which John Milton and Ezra Cornell alike accepted as ideal and the most needed elements of which, at the time and probably for years to come, are illustrated in the work of Sibley College.

"Cornell can be readily, and should be promptly, made the highest source of education, scientific and professional as well as academic, in the state and in the country. It, alone, is based upon the fundamental principle of the true university, as enunciated by Ezra Cornell, by John Milton and by Plato:—The university should teach any man any subject of educational value, including all the literatures, all the arts and all the sciences of the time."

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THE SIBLEY JOURNAL OF ENGINEERING,
ITHACA, N. Y.

NOTICE.

Alumni of Sibley College, receiving this copy of the JOURNAL, and not desiring to subscribe, are requested to inform us at once.

Copies of this issue have been sent to all Sibley College undergraduates. Those not wishing to subscribe, will kindly mark the copy "Refused", and leave same either at the Co-op, or with Andrus and Church.

GRADUATE students in Sibley College may be interested in the following clause in the Constitution of the JOURNAL:

"There shall be one Graduate Editor elected from among the graduate and special students in Sibley College by the members

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of the then existing board, advising with the Associate Editors. He shall be elected not earlier than November first and not later than November fifteenth."

All eligible men, who would be willing to accept such an election, are requested to see one of the Associate Editors or the Editor-in-Chief, at once, acquainting him with the fact. The Associate Editors will then recommend a man for the position of Graduate Editor, such a recommendation being usually tantamount to an election.

SOPHOMORES will be interested in learning that

"There shall be one editor elected from the Sophomore class *by the Board of Editors* during the month of May, said editor to serve during his Junior year."

Custom ordains that this position be filled as the result of a competition, which will close on the first day of May. The Editor-in-Chief will be pleased to talk with any Sophomore who may wish to enter this competition.

Two other sections of the Constitution are pertinent:

"There shall be one editor elected from the Junior class *by the members thereof* during the month of May, said editor to serve during his Senior year."

"There shall be one editor elected from the Sophomore class *by the members thereof* during the month of May, said editor to serve during his Junior year."

OF the many influences outside his regular work, which a Sibley man encounters, none is liable to render him such lasting benefit as membership in one or both—preferably both—of the two Engineering Societies of Sibley College. The Cornell Society of Mechanical Engineers held its initial meeting for the year on Oct. 7th; the Electrical Society of Cornell University was reorganized on Oct. 14th. Both societies have done good work in the past and are deserving of the support of all Sibley upperclassmen. Each is addressed on subjects of special and contemporaneous interest—mainly of a technical character—by men whose standing in their profession is at once the envy and the pride of their fellows, and many new lines of thought are opened up, which may well lead to important results. The meetings are full of interest and are almost invariably well attended. We advise and urge all Sibley upperclassmen to join either or both of these societies.

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THE Sibley Prizes were awarded at the last Commencement as follows:

First Prize, ... SIDNEY GRAVES KOON, 1902.
Second Prize, ... HOWARD WAIT RILEY, 1901.
Third Prize, ... JAMES LAWRENCE BATES, 1903.
Fourth Prize, ... EDGAR CALVERT WELBORN, 1903.
Fifth Prize, ... BARRETT SMITH, 1904.

Department Notes.

In the Department of Experimental Engineering, we will miss Mr. C. C. Major and Mr. T. M. Gardner. The former resigned to accept a similar position with the University of California, at Berkeley; while the latter was appointed a professor in Electrical Engineering, in the Pratt Institute, Brooklyn, N. Y.

These two vacancies were filled by the appointment of Messrs. Richard G. Dukes, E.E., '96, and R. L. Shipman, B.S., M.E., '99. Since graduation Mr. Dukes has been in Europe for some time, returning to the United States to accept a responsible position in the employ of the General Electric Co. Last year he was on the instructing staff of the Worcester Mass., Polytechnic Institute, having to deal with work in design and in the laboratories. Mr. Shipman has had a relatively large practical experience in the line of operating machinery. Just before coming to us he had charge of a large electric power station. An assistant in this Department has long been needed, and one has now been obtained by the appointment of Mr. R. G. Young, E.E., of the class of 1901.

To obtain a more logical arrangement and direction of the work the Sophomore Mechanical Drawing has been removed from the supervision of the Department of Drawing and Industrial Art, and placed under the Department of Machine Design. For similar reasons, the Junior Course in Steam Machinery has been divorced from the Department of Machine Design, and is now under the personal supervision of Dr. Thurston, to whose Course in Thermodynamics it forms the logical prelude. Mr. Shepard, who has immediate charge of this work, has also been appointed Assistant to the Director.

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Sibley College has for the last two or three years been crowded to its full capacity, but this year the congestion is much more marked than ever before. Exact figures are not obtainable at this date, but the following figures are not far from correct. In the College, 770 regular students, as against 654 last year (a high-water mark at that time). Of these, the Senior Class accounts for 120, Juniors 175, 225 Sophomores, and 250 Freshmen. The number of new men is abnormally large, being about 375. This means that about 125 of these men have entered some class other than the Freshman class. It is interesting to note that the Register announces the capacity of the College to be 600, of whom 200 may be Freshmen. Each of these figures has been exceeded by about 25 per cent.

Several important changes, due largely to the increasing number of students, have this year been made in the arrangement of the Sibley College curriculum. These affect mainly the work of the Junior year. The courses in Steam Machinery and in Electrical Machinery, which formerly consisted each of two recitations per week, have now been made four-hour courses, with a duration of only one term, instead of the whole year. This change greatly facilitates the handling of the large number of students now presenting themselves for instruction in these subjects, besides giving the student himself a chance to concentrate his attention upon *one* of these subjects at a time. The course in Electrical Machinery, which was last year, from the beginning of the second term, divided into two parts, one for students in Electrical Engineering, and the other for all other students pursuing the subject, has this year been so divided from the very start. Electrical Engineers have Steam Machinery during the first term, and Electrical Machinery during the second, thus retaining a better grasp of the subject, to apply upon the problems of their Senior year than if the two courses were reversed ; while the Mechanical Engineers, many of whom follow up Steam Engine Design during the Senior year, have the course in Steam Machinery last, and hence have a fresher knowledge of that subject than would otherwise be the case.

The course in Machine Design, which formerly consisted of two lectures and one recitation, per week, throughout the year, now calls for three lectures and one recitation per week, beginning after the Christmas recess. To fill the gap thus left in the work of the first term, the course in Materials of Engineering,

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formerly one hour per week for the entire year, is now made up of three lectures per week, ending at Christmas.

In the Sophomore year, a student no longer has Chemistry and Drawing simultaneously. He takes a six-hour course in Chemistry one term, and a five-hour course in Mechanical Drawing during the other term. It will be noted that one University hour has thus been added to the course in Drawing. The course in Descriptive Geometry now consists of two lectures and three hours of drawing per week, in place of the two recitations and two hours of drawing formerly required.

The Freshman has a similar schedule as regards Chemistry and Drawing, taking six hours of each, separately, for one term, instead of three hours of each, together, during the entire year.

Professor D. S. Kimball, for the past three years assistant professor of Machine Design, resigned during the summer to accept the position of Works Manager of the Stanley Electric Company, of Pittsfield, Mass. The general manager of the company, who was personally acquainted with the record of Professor Kimball, selected him for this responsible duty.

Professor Kimball's Sibley College friends, and particularly his former students, will deeply regret his separation from the College and will most fully appreciate the loss to the institution; though they will doubtless be pleased to know that his new field affords excellent professional opportunity, and, it is probably needless to state, a considerable pecuniary advantage.

Professor C. E. Coolidge has been elected assistant professor of Machine Design, to succeed Professor Kimball.

Mr. Coolidge served his time as a machinist (spending five years in shop and drafting room) with the Pratt & Whitney Co., of Hartford, Conn. He then entered the Sheffield Scientific School, of Yale University, where he completed the course in mechanical engineering. He was in the drafting rooms of the Pope Tube Co, of Hartford, for two years, during the installation of the great hydraulic machinery plant. Mr. Coolidge spent a year with the Eddy Electric Co., before he began to teach. He was instructor at Worcester Polytechnic Institute for a year, and Adjunct Professor in Mechanical Engineering for two years at the Georgia School of Technology.

Mr. Coolidge has also spent one summer as designer with each of the following concerns: Norton Emery Wheel Co., Worcester;

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Morgan Engineering Co., Worcester; Scott Printing Press Co., Plainfield, N. J.

He is the author of a book, recently issued, on Drawing and Descriptive Geometry. The varied practical experience of Professor Coolidge seems to fit him admirably for the work which his immediate predecessor conducted so ably.

The readjustment of work in Sibley College, due to the increase in the number of students, has necessitated the appointment of one additional instructor in machine design and one in mechanical drawing.

Mr. Sanford A. Moss, who is assigned to duty in the senior drafting room of the department of machine design, comes to us with a practical experience and theoretical training which fits him peculiarly for the work. He served his apprenticeship with the Phoenix Iron Works of San Francisco; then spent a year as draftsman for the California Gas Engineering Co., before he entered the University of California. Mr. Moss graduated at this institution in three years in the course in mechanical engineering. One year was next spent as draftsman at the Fulton Iron Works (San Francisco). The following year he was an assistant in mechanical engineering at the University of California, spending his mornings in that work while drafting for the Rix Engineering Co., and the Union Gas Engine Co., in the afternoons. He also completed graduate work leading to the degree of M.S. during this same year. The next year was spent in part as a graduate student at Cornell and in part as draftsman for the "Vimotum Co.," of Chicago. The following year he was engaged on construction work for this last named company, on motor cars propelled by gasoline engines. Another year was put in as designer for the Weber Gas Engine Co., of Kansas City; and the year preceding his call to Ithaca was spent in the offices of the General Electric Co. and the Schenectady Locomotive Works.

Practical experience on compressed air, refrigerating, mining, marine, and electrical machinery, gas engines, and locomotive work, together with a technical education, form an unusually complete basis for successful teaching along the lines of machine designing.

Mr. L. A. Harding, the new instructor in the mechanical drawing of the sophomore year is a graduate of the Pennsylvania State College, class of 1899. Since graduation he has been in the drafting room of the Dickson Locomotive and Manufacturing Co., Scranton, Pa., until last spring. The past summer was

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spent with the Lackawanna Iron and Steel Co., at Factoryville, Pa. Mr. Harding has, during his brief practical experience, collected and carefully arranged valuable notes on engineering practice, and has familiarized himself thoroughly with drafting office methods, and is, himself, an expert draftsman.

The new central building of Sibley College is not progressing so rapidly as was desired, due largely to delays in delivery of the stone, most of which comes from Indiana. The back wall, which is brick, has been entirely completed, and at this writing much of the structural steel is in place, including the circular form of the base of the dome, but the front wall has not reached the top of the first story windows. One advantage has accrued from the delay—the securing of a greater ability to handle the brick and structural shapes for the rear of the building, all of which have been carried by the large derrick in front.

Personals.

'98. Since our last issue appeared, Henry B. Brewster, E.E., has been appointed assistant engineer in the Bureau of Engineering, of the City of Syracuse. The appointment was made as the result of civil service examinations. Mr. Brewster was temporarily appointed to this position some time before.

'00. Richard H. Dearborn, M.E., has been appointed an Instructor in Mechanical and Electrical Engineering in the University of Oregon, where also, H. C. Howe, Cornell '93, is a member of the faculty. Cornell men have directed this line of work at that state university for many years.

'00. Virginius D. Moody, E.E., Edward L. Haines, M.E., and William E. Chase, E.E., are in the testing department of the General Electric Company.

'01. Maurice P. McKay, Ernest S. Holcombe, George W. Day, and George J. Millington, all E.E., are in the testing department of the General Electric Company.

'01. Frank Davies Newbury, E.E., Editor-in-chief of the 1900–01 Board of the SIBLEY JOURNAL, Louis A. Rice, E.E., and Howard L. Gilbert, E.E., are with the Westinghouse Electric and Manufacturing Company, at East Pittsburg, Pa.

'01. A. S. Langsdorf, M.M.E., is in the faculty of the Department of Electrical Engineering, in the Washington University, at St. Louis, Mo. He spent the summer in the shops of the General Electric Company.

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'01. A. S. McAllister, M.M.E., has a well-considered article on "Parallel Operation of Alternators", in the September *American Electrician*. He discusses at length the cross current between two machines so operated, and the remedies necessary to correct this source of loss.

Mr. S. Yamasaki, of Tokio, a graduate of the Imperial Japanese University, has entered the University and Sibley College to pursue graduate studies. He brings letters from Mr. Yoshimaro Takatsuji, E.E., '98, who is now at the Imperial University. Professor Hatsuné Nakano, M.S., '89, formerly a student in electrical engineering at Cornell, is the present head of that department at Tokio.

Sibley College is well represented in the drafting room of McIntosh, Seymour & Co., of Auburn. The following men were in the employ of this company during the summer: C. L. Jeffrey, E.E., '93; Henry Brewer, M.E., '94; F. D. Purdy, M.E., '96; Lyndon B. Taylor, E.E., '97; Roy M. Stanley, E.E. '98; W. V. Delano, M.E., '98; Sidney G. Koon, '02.

BOOK REVIEW.

The Power Quarterly. Published by The Power Publishing Co., New York, $1.00 per year.

The September number is devoted to the Pan-American Exposition, and contains a large amount of matter relating to the principal exhibits of power-furnishing machinery. Engines, gas-engines, and the main electrical machinery exhibits are dealt with at length. The illustrations number about 140.

Linear Drawing and Lettering. By J. C. L. Fish, C.E., (Cornell '92) Assoc. M. Am. Soc. C.E., Associate Professor of Civil Engineering in Leland Stanford Junior University. Published by the Author, Palo Alto, California, 1901. 7x10½ oblong. v + 65 pp. 50 figures. Limp cloth, $1.00 post-paid.

Blank Book for Lettering. To be used with "Linear Drawing and Lettering." By J. C L. Fish. 7x10½ oblong. 30 sheets. Paper, 25 cents, post-paid.

This book, which is stated to be for beginners, comprises chapters on Instruments and Materials, Linear Drawing, Lettering, and Introduction to Drafting. Very complete and excellent instructions are given for the care of drawing instruments and other materials, for performing various drawing exercises calculated to induce in the beginner a familiarity with the use of his instruments, for preparing a number of plates required of beginning students in engineering in the Leland Stanford Junior University, and for making letters of a number of different styles, and uniting them to form titles for drawings.

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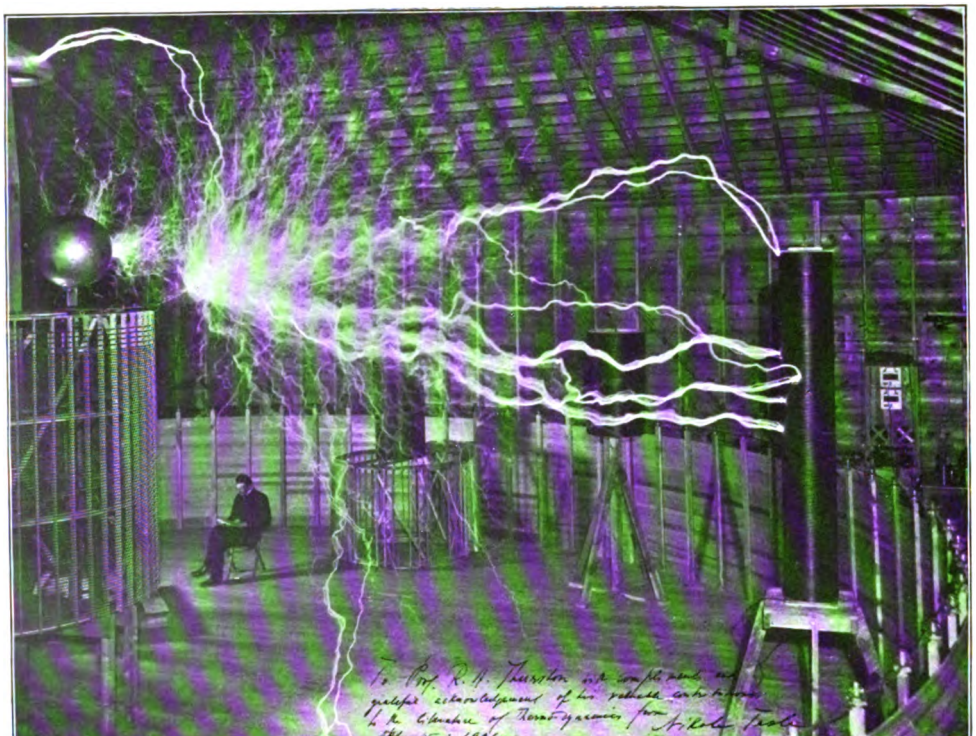

TESLA'S ARTIFICIAL LIGHTNING.

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THE SIBLEY JOURNAL OF ENGINEERING.

VOL. XVI. NOVEMBER, 1901. No. 2.

IN CORNELL UNIVERSITY.

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislature of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

THE INFLUENCE OF CLEARANCE AND COMPRESSION ON THE CONSUMPTION OF STEAM.*

H. DUBBEL.

(*Concluded.*)

(*B*) *With Condensation.*

In order to observe compression with a condensing engine, Dwelshauvers-Déry undertook further:

3 trials with 60 per cent. compression, in March, 1898.
3 " " 40 " " " " " "
6 " " 10 " " " " March and April, 1898.

In these trials the admission amounted to 10 per cent., release, 5 per cent. (before end of stroke); the ratio of expansion was 5.67.

Table II contains the results of this investigation, showing that both condensations increased with increasing compression as in Fig. 7. The consideration of the compression curve shows, that with 10 per cent. and 40 per cent. compression, the steam at the

*Translated by S. G. Koon, from *Zeitschrift des Vereines deutscher Ingenieure.*

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TABLE II.

Date of trial		6 April, 1898	15 March, 1898	10 March, 1898
Compression begins at	Per cent.	10	40	60
R.P.M.		46.91	47.00	46.97
Boiler pressure	at. abs.	5.55	5.54	5.59
Initial temperature of the superheated steam	°C	196.7	200.4	197.4
Heat equivalent of work indicated per stroke	Heat units	1.7101	1.5821	1.3956
Steam consumption per stroke M_s	Kg.	0.028266	0.027190	0.028231
Quantity of heat required in cylinder per stroke Q	Heat units	19.0514	18.3758	19.0364
Steam consumption per H.P. per hour	Kg.	10.445	10.921	12.808
Weight of the mixture remaining in the cylinder and taking part in the compression M_c	Kg.	0.000767	0.002178	0.004101
Specific quantity (*i. e.*, quality) of steam at end of compression X_3		superheated	superheated	0.899
Quantity of heat transferred to walls during compression R_c	Heat units	0.0072	0.1542	0.6104
Weight of expanding mixture $M_s + M_c$	Kg.	0.029033	0.029368	0.032332
Weight of steam in cylinder at end of admission M_o	Kg.	0.017616	0.017585	0.017573
Initial condensation during admission R_s	Heat units	6.6599	6.8165	7.9835
Ratio of quantity of heat lost by initial condensation, to total quantity of heat $R_s : Q$		0.3496	0.3709	0.4194
Heat-loss caused by condensation, net, $R_c + R_s$	Heat units	6.6671	6.9707	8.5939
Ratio of this loss to total heat $(R_c + R_s) : Q$		0.3500	0.3793	0.4514
Heat returned to steam during expansion R_d	Heat units	3.3127	3.4836	3.7191
Ratio of this quantity to total heat $R_d : Q$		0.1739	0.1896	0.1954
Total value of heat lost during compression, admission and expansion $R_f = R_c + R_s + R_d$	Heat units	3.3544	3.4871	4.8748
Ratio of this lost quantity to total heat $R_f : Q$		0.1761	0.1898	0.2561
Weight of steam in cylinder at end of expansion M_x	Kg.	0.023037	0.023348	0.024033
Specific quantity (*i. e.*, quality) of this mixture X_x		0.7935	0.7950	0.7433
Heat contents of same U_x	Heat units	14.3050	14.4970	15.1362
Ratio of this heat to total heat $U_x : Q$		0.7509	0.7889	0.7951

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beginning became largely superheated, while in the course of the compression, the temperature again decreased, without, however, causing the steam to become wet; only with 60 per cent. compression did some 10 per cent. of water appear at the end.

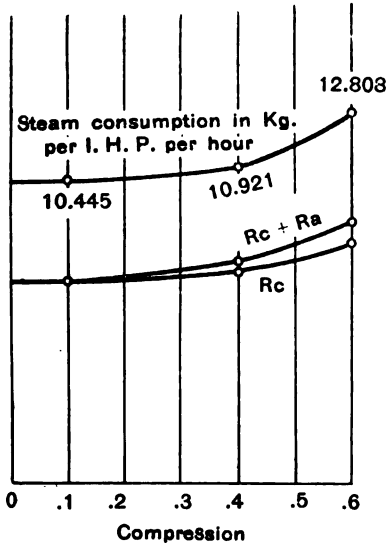

FIG. 7.

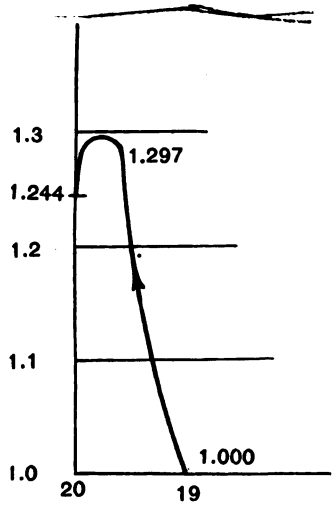

FIG. 8.

Dwelshauvers-Déry represents the change of the condition of the compressed steam by the curves, Figs. 8 to 10, whose abscissae are piston positions during compression, and whose ordinates represent the changes of M: M_0, in which $M = Vd$, the volume of the compression at any point $\times$ the weight of the steam per cubic metre, calculated from the pressure at this point, and M_0 is the volume at the beginning of compression $\times$ the weight of the steam per cubic metre, at the corresponding pressure. If $M : M_0 < 1$, as is the case in Fig. 10, the steam is moist.

The curve represented in Fig. 10 for 60 per cent. compression, shows at the beginning of the stroke a very small quantity of steam in the cylinder, as in Doerfel's tests with high compression. Dwelshauvers-Déry has calculated six of his tests under different conditions of the specified quantity of steam X at the beginning of compression, where by the final heat loss R_t was influenced as indicated in Table III. The tests without condensation show an insignificant increase in the heat loss R_t with the moisture in the steam while in the tests with condensation the reverse is the case.

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In the last few tests R_f increases continually with the degree of compression, no matter whether a larger or less degree of moisture is supposed. The radiation loss $E=R_f-R_e$ (where R_e represents the quantity of heat given back from the walls during exhaust) is for all three nearly equal to X.

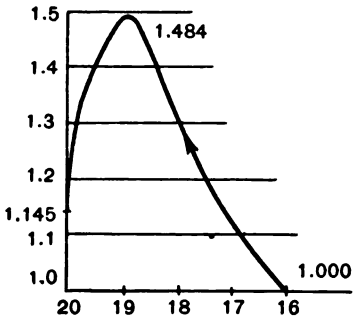

FIG. 9.

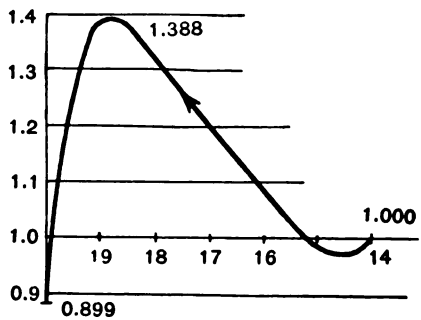

FIG. 10.

TABLE III.

Final heat-loss R_f under different accepted values of x.

			$x=1$	$x=0.5$	$x=0.25$
Non-condensing	0% compression	7th Sept., 1897	8.17	12.61	21.48
Non-condensing	30% compression	10th Sept., 1897	24.04	24.29	24.79
Non-condensing	40% compression	16th Sept., 1897	22.74	23.09	23.78
Condensing	10% compression	6th April, 1898	17.61	17.45	17.12
Condensing	40% compression	15th March, 1898	18.98	18.50	17.54
Condensing	60% compression	10th March, 1898	25.61	24.85	23.35

Objections have been raised against these tests by Professor Boulvin, who contends that the piston and valves of the trial engine were leaky, while Dwelshauvers-Déry replies that the leaks measured by him before the test did not exceed the usual amount. In fact this objection is not of great importance, as all commercial engines have more or less loose pistons and valves, and furthermore the tests of Callender and Nicholson have shown that parts which are tight when the engine is at rest, where most trials for leaks are made, may often not be tight during use.

(*C*) *With Changing Compression and Constant Load.*

After careful examination of the foregoing results the well-known American engineer, Isherwood, in a communication addressed to Dwelshauvers-Déry, brings forward the assertion

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TABLE IV.

		Without compression	40% compression	60% compression	60% compression without superheating
Steam consumption per I.H.P. per hour	Kg.	11.129	11.118	11.213	13.432
R.P.M.		49.26	46.49	47.76	48.73
Boiler pressure	Atmos. abs.	5.2749	5.4870	6.1797	6.2678
Temperature of superheated steam	°C	207.340	202.637	205.606	159.830
Steam consnmption per stroke M_s	Kg.	0.027219	0.027358	0.027586	0.033657
Heat consumption per stroke Q	Heat units.	18.4947	18.5183	18.6923	22.0519
Equivalent of the indicated work $A\tau$	Heat units.	1.5589	1.5643	1.5632	1.5352
Quantity of heat lost to condenser $C+C$	Heat units.	16.5048	16.4951	16.5515	19 9996
Barometer pressure	M.m.	10.214	10.379	10.174	10.251
Absolute work $A\tau_{abs}$ from the diagram	Heat units.	1.7781	1.8974	2.1708	2.3499
Negative work $A\tau_{neg}$ from the diagram	Heat units.	0.2208	0.3347	0.6064	0.7900
Indicated work $A\tau$ from the diagram	Heat units.	1.5570	1.5642	1.5644	1.5599
Least back pressure	Atmos. abs.	0.1634	0.1532	0.2307	0.2813
Heat exchange during compression R_c	Heat units.	. . .	0.1310	0 4770	0.8223
Heat exchange during admission R_a	Heat units.	7.1559	7.6237	7.5807	10.1248
Heat exchange during both together R_c+R_a	Heat units.	7.1559	7.7546	8.0577	10.9471
Heat exchange during expansion $-R_d$	Heat units.	4.2544	4.3354	4.6438	6.6651
Heat exchange during all three together R_f	Heat units.	2.9016	3.4193	3.4140	4.2820
Heat exchange during exhaust R_e	Heat units.	2.4692	2.9600	2.8408	3.7895
Loss by radiation E'	Heat units.	0.4324	0.4592	0.5731	0.4925
Ratio of the following heat quantities to Q.	$A\tau_{abs}$	0.0962	0.1025	0.1162	0.1066
	$A\tau_{neg}$	0.0119	0.0169	0.0325	0.0358
	$A\tau$	0.0843	0.0845	0.0837	0.0708
	R_c	. . .	0.0071	0.0255	0.0373
	R_a	0.3866	0.4114	0.4054	0.4592
	R_c+R_a	0.3866	0.4185	0.4309	0.4965
	$-R_d$	0.2299	0.2348	0.2485	0.3025
	R_f	0.1567	0.1842	0.1824	0.1941
	R_e	0.1333	0.1595	0.1517	0.1717
	E'	0.0234	0.0248	0.0306	0.0223

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that the consumption of steam is nearly proportional to the absolute work, and that this was constant in the tests. Furthermore that the differences found in steam consumption shown by the indicated horse power, could be ascribed to the change in the negative work due to the changing compression.

The error of this view is easily proved, as, with constant indicated horse power but increasing compression the steam consumption calculated as above, decreased, while the absolute power ven increased. In spite of this fact Dwelshauvers-Déry undertook further tests in which, in fulfillment of the conditions imposed by Isherwood, the load of the engine was unchanged. From March to May, 1899, 10 trials without compression, 10 with 40 per cent. compression, and 6 with 60 per cent. compression were made; and the last few, part with, and part without, superheating. The mean results from the best tests are given in Table IV.

The results show that the sum of the condensations $\frac{R_c + R_a}{Q}$ again increases with the compression from 38.66 per cent. to 43.09 per cent. corresponding with 0 per cent. to 60 per cent. compression. The harmful influence of the walls $R_c + R_a$ grows with the compression, just as does the heat-delivery from the walls to the expanding steam; so that the sum of the losses $R_c + R_a + R_d$ in all cases remains almost constant.

Although Dwelshauvers-Déry himself considers these results to support Isherwood's assumption, they confirm the conclusions to be drawn from the first tests.

(3) TESTS OF BARR AND CARPENTER.

Trial engine: High pressure cylinder of triple expansion, Corliss Engine of Sibley College, Cornell University. Diameter of cylinder, 228.6 mm. (9″), stroke 914 mm (36″). Size of clearance on head end, 7.4 per cent., on crank end, 7.45 per cent. The engine worked without steam jacket and non-condensing. The steam consumption was measured by condensing the exhaust. On this engine Professor Barr made tests, first, in order to demonstrate the advantage of regulation through the simultaneous changing of cut-off and compression.

Professor Barr took the correct view that the earlier the cut-off, the greater the initial condensation per horse power; because in this case, on the one side, the power is diminished, on the other hand the cylinder walls come in contact for only a short time with steam at a high temperature, so that the mean wall temperature

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falls. This decrease in temperature was to be avoided by higher compression, which in turn was to decrease the exhaust loss through the earlier cut-off. The valves were so set for these tests that the admission occurred immediately after the compression had attained initial pressure. A series of tests were first carried out with two different loads, then under the same conditions a second series of trials with ordinary regulations was undertaken.

TABLE V.

Number of test		I.	II.	III.
R.P.M.		85.1	85.0	84.9
Boiler pressure (gauge)	Atmos.	5.	4.93	4 76
Vacuum in condenser	Atmos.	0.2	0.211	0.18
Cut off	Per cent.	21.2	21.6	21.4
Release	Per cent.	98.9	98.5	98.9
Compression	Per cent.	11 4	25.0	35.2
Initial pressure (at cut off)	Atmos. abs.	5.648	5.60	5.62
Final pressure in compression	Atmos. abs.	2 40	3.732	4 90
Exhaust pressure	Atmos. abs.	0.9366	0.9366	0.9366
Indicated power (head end)	H.P.	16.1	14.7	13 84
Indicated power (crank end)	H.P.	15.9	15.5	14.17
Total indicated power	H.P.	32.0	31.2	28.01
Effective power	H.P.	30.0	29.0	26.0
Mechanical efficiency	Per cent.	93.7	92.7	92.7
Steam consumption per I.H.P.	Kg.	14.0	14.23	14.4
Steam consumption per D.H.P.	Kg.	15.02	15.12	15.44
Steam consumption according to the diagram calculated at cut-off	Kg.	8.54	8.49	8.72

Professor Barr ascribes the high steam consumption in the compression tests principally to the great falling off of pressure at the end of the stroke, as the admission is naturally greater in these tests than in those without compression, equal power being presupposed. Further he draws attention to tests in the same laboratory, which like those of Callender and Nicholson showed that on opening the exhaust valves, vaporization of the water on the cylinder walls followed almost instantly through fall of pressure; so that an earlier closing of the exhaust cannot alter much the loss of heat by exhaust steam..

The tests of Professor Carpenter on the same engine extended to the three different grades of compression.

The results are given in Table V. The values in Table VI were obtained by Professor Carpenter, with further tests upon the regulation through changing compression.

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(4) TESTS OF PROFESSOR JACOBUS.

Trial engine: steam engine in Stevens Institute of Technology. Diameter of cylinder 254 mm. (10″), stroke 279 mm. (11″), initial pressure, 4.9 atmospheres, R.P.M. 250. The engine worked without steam jacket and without condensation.

TABLE VI.

Number of test		A	B	C	D
Duration of test	Hours.	3	3	3	3
Average load	I.H.P.	13.15	13.98	24.79	25.79
Steam consumption per I.H.P. per hour	Kg.	19.87	19.81	14.28	15.98
Cut-off	Per cent.	1.5	17.5	4.5	26.3
Initial pressure (gauge)	Atmos.	7.465	7.60	7.676	7.6
Final pressure, compression (gauge)	Atmos.	1.4	8.31	1.34	8.45

The diagrams were taken every five minutes. The steam consumption was determined by weighing the condensed exhaust steam. Every fluctuation of brake load was carefully avoided in order not to influence the steam consumption per H.P. hour. The steam leak of the valves measured with the engine at rest was insignificant. Large compressions were produced by setting two

TABLE VII.

	Cut-off. %	Power. I.H.P.	Actual steam consumption per I.H.P. Kg.	Steam cons. per I.H.P. drawn on the enlarged diagram. Kg.
1. Series of tests: Compression up to initial pressure	25	20.87	17.34	17.21
2. Series of tests: Compression to ⅔ initial pressure	25	20.20	18.21	16.66
3. Series of tests: Compression to ⅚ initial pressure	25	20.72	17.12	15.8

different exhaust valves, one of which gave compression up to initial pressure, but slightly advanced release; the other, less compression but greater advance of release. In order to obtain

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approximately the steam consumption for equal angle of release, Professor Jacobus prolonged the expansion lines in the diagram with great advance of release.

There were three separate sets of investigations carried out: each consisted of a number of separate tests whose length varied from 40 to 120 minutes. Table VII shows the results obtained.

The tests here discussed, whose authors enjoy the greatest respect in the technical world, and which have been undertaken with the most widely divergent classes of engines, leave no doubt that compression at least does not increase the effect of clearance. While in the tests of Doerfel, Barr, Carpenter and Jacobus, the increased consumption of steam with increasing compression is only insignificant; those of Dwelshauvers-Déry show greater differences in steam consumption, whose origin finds an explanation perhaps in the looseness of the valves and the piston.

THE MANUFACTURING INDUSTRIES: THEIR RELATIONS TO NATIONAL POSITION AND PROGRESS.*

ROBERT H. THURSTON.

A retrospect of the XIXth Century and a study of the industrial progress of the nations during that period and of the situation to-day is sufficient to convince any intelligent and unprejudiced mind of the fact that advancement in civilization depends upon progress in the industries of the people. While civilization and general intelligence may, as in Greece in classic times, pervade an aristocratic class, and while comfort and luxuries may at any time be secured by the rich, it is only when our manufacturing industries—and the agricultural industries and those of mining, in fact all productive industries, are falling into that category—it is only when our industries are prosperous and productive and when, therefore, the people may in maximum degree share the comforts and luxuries with the rich, that national progress can be assured. Substantially all of the extraordinary progress of our country and of the civilized world which has been witnessed during the last century, and particularly since the revival of industries about 1870, has been effected through

*Abstract of an Address, by request, before the New England Cotton Manufacturers' Association, in Convention at Niagara Falls, Sept. 25-26, 1901.

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the promotion of improved methods, the adoption of scientific systems and the introduction of universal and cheap intercommunication and transportation.

The great economic question of every nation and of all times to come is now clearly seen to be: How shall the industries be most effectively sustained and promoted as a basis for all moral, intellectual and material advancement? The answer is coming to be no less well and definitely determined: Industry, scientifically utilized, is the needful thing.

The foundation of the whole marvellous advance of the last generation and of the less remarkable, but still impressive, advances of the earlier decades of the century, was laid when the inventors of the steam-engine and of the spinning frame and the power-loom, of the whole modern system of textile manufactures, in fact, made it possible to effectively utilize the powers of nature and the skill and intelligence of man, in conjunction, in the construction of a national system of manufactures; thus giving a single worker ability to produce as much, in these later years, as then could a score.

The industrial world is one in which the human hand and brain, working to a common end, find ingenious mechanical combinations and discover new methods by which the labor-assisting machine may be made to do the work of the world more and more completely and thus reduce the working time and lighten the labor of the people, permitting the rapid accumulation of wealth in forms of permanent value. The world of agriculture is coming to be a world of mechanics and its people are more and more segregating where they find life most attractive and are finding, more and more generally, ways of securing, for themselves and their children, comfort, competence, education, freedom from anxiety and certainty of ample reward for lives of industry, ambition, frugality and of intelligent use of their physical and mental powers.

One impressive aspect of the industrial changes of the century just expired is the tendency of all departments of industry to become systematized, to take on organization and especially to secure the aid of labor-assisting machinery, becoming branches of mechanical engineering.

Thus: farming became, in the later years of the XIXth Century, systematic and scientific agriculture and is now conducted in all its larger details by machinery. Ploughing, sowing, reaping, binding, threshing, grinding the grain, taking it to market,

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transporting it to city or distant country and across the ocean to feed other nations: all is done, to-day, by machinery and this branch of mechanical engineering now equalizes the distribution of the food of the world, sends the surplus of one district to the starving people of another in which crops have failed, and permits a world-wide system of constant adjustment of supply to demand.

Cotton, wool, flax and silk, all textile processes, have come to be materials and methods of mechanical engineering. Mills containing a hundred thousand spindles are furnished with steam engines of four thousand horse power and upward, distributing power to all departments, from pickers and carding machines to spindle and loom, through electric wires, retransforming it at the distant point of application by electric motors and driving, thus, every machine at its proper speed and with necessary force throughout acres of floor, reinforcing the minds and hands of the thousands of operatives gathered together to supply their thus many-times multiplied powers to the correspondingly multiplied advantage of their fellows and themselves. The textile factory is a great machine and the most impressive illustration, perhaps, of our time, of this tendency to convert all industries into branches of mechanical engineering.

Metallurgy almost as strikingly illustrates the same evolution. Iron ore, for example, is now taken from its bed by steam shovels, loaded into ore-trains, transported by steam to tide-water and transferred to the hold of a steam vessel of thousands of tons capacity, specially adapted in construction to this purpose; transfer being effected by powerful and largely automatic machinery. It is then transported by ship and by train to the iron works where it is once again transferred by machinery to stock-house or to blast-furnace and converted into molten cast iron; this runs out of the furnace, flows into a steadily moving series of moulds in the "casting machine", cools as it travels towards its destination and is finally deposited in neat and compact layers and rows in the stock-yard. Machinery later transports it to the steel-making and rolling mills; machinery drives the mechanisms of the converter and the apparatus of the open-hearth furnace, machinery transfers the product, as steel, into the ingot moulds and from the moulds to the mills. Steam power of enormous quantity compresses and forms and shapes to guage the hot, soft mass and passes the piece from roll to roll and from point to point in the mill, until it appears, ready for the

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market, as rail, beam, bar or wire; machinery doing the work and the hand and the brain of man simply guiding the unconscious product and servant of the human mind, from beginning to end. Sent into the market, the various shapes are taken into other mills and factories and there, by other mechanical engineering systems, are converted into new and useful forms, aggregated into machines, tools, and motors capable of driving all other machines and tools, and a cycle is completed.

* * * * *

Another generation will see the whole industrial system of the United States practically under the hands and direction of the technically trained men. All the great corporations engaged in manufacturing are falling under the supervision and are subject to the energetic and discreet management of these young men, trained in the sciences as well as the arts of their chosen vocation. The extent to which this change has taken place is a matter of astonishment to all familiar with the fact, but unfamiliar with the enormous difference in value between the so-called "practical" man without scientific knowledge and the young professionally trained engineer, well educated, familiar alike with the facts and the reasons for them, and capable of making himself "practical" in a wonderfully short time, then constituting the ideal "captain of industry." The great successes in this department of life in the United States are of young men of this class. Fighting their way into the superintendencies of shops, mills, factories, railways, and great manufacturing industries, they are rapidly proving the value of a combination of scientific knowledge with talent and practical experience. They are a selected class; for every man of them, in the case at least of the great schools of engineering, must have secured his admission by meeting entrance requirements that the average youth can rarely attain, even if—as all these young men must be, to succeed—naturally fitted for the professional work of the school. This includes, usually, shop-work, drawing, designing, chemical, physical, mechanical, electrical engineering, laboratory work, often serious research supplementing instruction. The student's fingers and brain are alike cultivated, through four years of the most arduous work known in our colleges, in even the professional schools.

It may not be the fact that our technical schools have had a very important influence in the past; but they are exerting a wonderfully powerful influence now, and will exert a vastly greater power hereafter in the uplifting of our "curves of progress."

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ACETYLENE GAS.

HENRY C. EARLE, M.E., '95.

The progress that acetylene gas, as an illuminant, has made in the last few years is no better shown than by the fact that at the Chicago fair in 1893, there was no exhibit of gas or the apparatus for making it, while in 1901 at the Pan-American Exhibition there is a special building devoted to showing the light, with the generators and other articles connected with it. Here are shown search lights for yachts, and lamps for bicycles and automobile as well as for the house. It is supposed that there are 40,000 acetylene generators in use in the United States, which are lighting stores, factories, churches, residences, and all manner of places, as well as some that are lighting whole villages or sections of cities.

This introduction into actual use has been made for the most part during the last four years, and against all the opposition of the powerful oil, gas, and electric light interests, and in spite of the poor machines that were often put out in the early stages of the business. The advance has been due directly and only to the good qualities of the light. In the best installations, the claims made for acetylene by its friends are: It is the best artificial light in the world for general use; that it is a cheap light; that it is a safe light, and that it is a convenient light.

To enter more in detail into these claims, it may be stated that it is the best light because it is almost identical with daylight; a spectrum analysis shows the same proportion of the components, and no light is better than sun-light. As a result of this, colors are matched well as by no other artificial light, and photographs are taken. It is whiter than the Welsbach mantle, or the arc electric, while softer. It burns without smell, smoke or noise.

That it is a cheap light is shown by the fact that it is equivalent to good city gas if the latter is sold for seventy-five cents a thousand cu, ft. (as it never is), while city gas at $1.50 is less expensive than incandescent electric lights. In the actual amount of light given, acetylene will compare quite favorably with kerosene in price and is cheaper than candles.

In safety it is neither better nor worse than city gas, under like conditions; but it should be noticed that acetylene always gives a prompt warning of its presence by its peculiar odor, and as the

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regular burner will pass but ½ foot of gas in an hour, it is not easy to get a large amount of gas into a room in this way. Also acetylene is never put in with lead pipes at the meter, as is city gas, and this source of disastrous fires is eliminated in the case of acetylene. Many very severe fires have been due to the escape of gas from the pipes that were burned off in the early stage of some fire, which otherwise would have been unimportant. The number of fires and fatal accidents from electric wires, places this latter means of lighting as one of the most dangerous; and on the whole acetylene, while it has often been said to be dangerous, is in many respects one of the safest methods of illumination.

Of the present users of this modern gas, by far the greater number use an automatic generator of their own, and so are the gas company and the only customer. The machine located in any convenient place where there is no danger of freezing, occupies little room, and does nearly all the work, demanding only that it be kept supplied with carbide and water, and that the waste be run off. A house-size generator is not over 26 by 54 inches on the bottom and perhaps 50 inches high, and should run at least a week without care. During this time the user turns on or off his gas with as little thought of the source of the gas as does the customer of the city gas company. It is this ease of management, with the splendid quality, that has placed so many acetylene generators in the homes of out-of-town people.

The principle of these generators is usually quite simple; a supply of gas under a gasometer is drawn on when the light is in use, and the downward motion of the gasometer caused by the withdrawal of this gas causes a small amount of calcium carbide to fall into the tank of water below, with the immediate result that enough gas is made to send the gasometer up a few inches; another drop will in the same way make a new supply. If no gas is used, none is made, and the machine will stand with its small supply for a long time without loss or disadvantage.

The calcium carbide mentioned is, as its name shows, a union of carbon and lime. It is made by melting in the electric furnace, powdered coke and lime; 37 parts of the former to 63 of the latter. At a temperature of over 6,000 degrees F., these unite into the hard rock-like material commonly called "carbide". The general price of this is $3.75 per hundred pounds, and a pound will make a little less than 5 cu. ft. of gas by simply allowing water to reach it.

Besides the private generators as mentioned, acetylene is now coming to be used in a larger way, and about 40 towns have a

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public system of lighting or a co-operative plan among a great number of the residents. This plan of town lighting is growing to larger and larger places, and is of immense advantage to the places where it is installed. The small cost of an acetylene plant as compared with the cost of an electric light plant, makes it possible to put this light into places that cannot support an electric company, and yet the town will get its light at a lower cost than the larger cities, where electric plants have been installed. The usual price of acetylene gas when sold by meter seems to be $1.50 per 100 ft. As acetylene has 12 times the candle power of coal gas this is equivalent to the latter at $1.25 per 1,000 ft., a price lower than prevailing, except in the larger cities. At this price a 22 candle flame costs 0.6 of a cent an hour, while in those towns that have electricity a 16 c. p. incandescent costs about 1 cent per hour, and is very much poorer light. In a town in which the writer is now interested, the price has been set at $1.2
100 cu. ft., equal to city gas at $1.00 per 1,000 ft., and yet this is a small village in Massachusetts, having only about 900 inhabitants. They—more fortunate than their neighbors, who are larger in number—will have a better light than the people in Boston and at the same cost for an equal amount. This plant which is now about half installed, will include 50 street lights for which the town pays, and lights for all the customers that can be obtained, as it is a regular corporation formed to make money by lighting this town. It is probable that in the next few years the small villages will be supplied with acetylene gas as rapidly as those places with more inhabitants were supplied with electric railroads some years ago.

As yet there is no city where acetylene and coal gas have come into direct competition; if they should, the result would be watched with interest and would depend largely on the financial management, more than on the properties of the lights. The gas companies have the advantage of being able to supply gas for heating; a field where the acetylene companies are almost barred, when city gas can be had. One solution of the fight might be a lowering of the cost of the gas of the older company, who could supply a water gas for heating at a very low price, thus abandoning the lighting field largely to the acetylene and arc lights, while greatly extending the sales of gas for heating purposes. Before such a competition comes however, the acetylene field will travel along the lines of least resistance, which is through the places which at present have no light; here they are welcome and have no oppo-

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sition. When these villages are well supplied, and the results of the work in the small places are known, it is not at all unlikely that the present city gas companies will find a rival that will be harder to oppose than electricity has been, and the electric light companies may be obliged to resort largely to their arc lamps for their source of revenue. That some better light for small general purposes, and at a low price, is wished in all cities, is a well known fact. That acetylene can fill this want is getting to be known. To apply the remedy to the trouble is a small problem in engineering, and almost purely a financial one.

HE EFFICIENCY OF THE BICYCLE RIDER AS A MACHINE.

R. C. CARPENTER.

(*Concluded.*)

From data given earlier in this bulletin we know the distance ridden each day and the time spent in riding, from which we may comput e the average speed per hour. The total resistance due to gear and tire friction and to wind pressure may also be computed. These results are shown in Tables 4 and 5. The values in the fifth column for resistance due to wind pressure are taken from the average speed per hour. Those in the fifth column, bicycle resistance, are found in the following manner: The total resistance will be equal to the wind resistance plus the gear resistance and the tire resistance * of both wheels. The total

* In the computation for the total resistance of the bicycle the friction work of the gearing and the friction work of the two wheels have been added. In a previous calculation, to which reference has been made, the total wheel resistance was taken as that of the gearing plus that shown by the dynamometer for one wheel, it being at that time thought that the work of friction of the rear wheel when running on the dynamometer was nearly equal to that of two wheels on a level surface, for the reason that the power was absorbed by a wheel of about the diameter of the bicycle wheel on which the rear wheel rested and which was put in motion by the rear wheel.

Subsequent investigation seems to indicate that the track friction is practically independent of the size of the dynamometer wheel which absorbed the work, and consequently to obtain the full resistance of the bicycle it is necessary to add that caused by the gearing to twice that due to one wheel

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resistance in foot-pounds per minute multiplied by 60 gives the amount of work done each hour, and this latter quantity multiplied by the number of hours spent on the wheel gives the total amount of work done during the day. The heat equivalent of

TABLE IV.

ENERGY SUPPLIED AND WORK DONE (*a*) BY C. W. MILLER.

Date.	Distance covered each day.	Time spent on wheel each day.	Average speed per hour.	Resistance overcome per minute.				Total work done each day.	Heat equivalent of work done.	Total energy in food.
				Bicycle.	Wind.	Total.				
	Miles.	*Hours.*	*Miles.*	*Foot-pounds.*	*Foot-pounds.*	*Foot-pounds.*		*Foot-pounds.*	*Calories*	*Calories*
Dec. 5	441.8	23.16	19.07	1,927	9,000	*c* 10,927		15,184,159	4,917	5,900
6	366.7	21.16	17.32	1,692	6,750	8,442		10,717,963	3,471	4,108
7	334.1	20.18	16.55	1,590	5,850	7,440		9,008,352	2,917	6,577
8	316.5	19.72	16.05	1,542	5,325	6,867		8,125,034	2,631	2,890
9	327.8	19.62	16.71	1,587	6,000	7,587		8,931,416	2,892	4,238
10	220.5	14.23	15.46	1,508	4,950	6,458		5,513,840	1,786	6,788
Average 6 days	334.6	19.68	17.00	. . . .	. . . .	. . . .		9,580,127	3,102	*b* 4,993
Average 5 days	357.4	20.77	17.20	. . . .	. . . .	. . . .		10,393,385	3,366	. . . .

a Exposure assumed to be equivalent to 3 square feet.

b The energy in the food for individual days is computed by use of factors as explained above. The average for the six days was determined by burning samples of the foods in the bomb calorimeter, and hence differs slightly from the computed average. Energy metabolized from body not considered in table.

c Equivalent to 0.331 horse power.

as shown by the dynamometer. This hypothesis may be slightly in error and may make the tire resistance greater than that actually overcome, but the correction is not relatively a large one, although sufficient to reduce the total resistance about 7 per cent. and make a corresponding reduction in the efficiency of the rider.

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the work done is computed by dividing the total number of foot-pounds by the mechanical equivalent of 1 calorie—3,088 foot-pounds. From the data and computations given in Table 4 it would appear that the heat equivalent of the average amount of work done by Miller per day was 3,102 calories, while the total

TABLE V.

ENERGY SUPPLIED AND WORK DONE (*a*) BY FRANK ALBERT.

Date.	Distance covered each day.	Time spent on wheel each day.	Average speed per hour.	Resistance overcome per minute.			Total work done each day.	Heat equivalent of work done.	Total energy in food.
				Bicycle.	Wind.	Total			
	Miles.	*Hours.*	*Miles.*	*Foot-pounds.*	*Foot-pounds.*	*Foot-pounds.*	*Foot-pounds.*	*Calories*	*Calories*
Dec. 5	402.0	22.66	17.75	1,745	7,200	8,945	12,161,622	3,938	5,862
6	371.3	21.28	17.40	1,703	6,870	8,573	10,946,006	3,545	4,387
7	352.7	20.68	17.10	1,683	6,550	8,233	10,215,506	3,308	6,563
8	285.3	17.21	16.60	1,602	5,925	7,527	7,772,380	2,517	7,977
9	229.4	14.50	15.85	1,550	5,250	6,800	5,916,000	1,916	7,704
10	181.9	12.38	14.60	1,420	4,125	5,545	4,118,826	1,334	6,124
Average 6 days	303.8	18.11	16.80	. . . .	. . . .	. . . .	8,521,723	2,760	*b* 6,307
Average 5 days	328.1	19.26	17.05	. . . .	. . . .	. . . .	9,402,303	3,045	. . . .

a Exposure assumed to be equivalent to 3 square feet.

b The energy in the food for individual days is computed by use of factors as explained above. The average for the six days was determined by burning samples of the foods in the bomb calorimeter, and hence differs slightly from the computed average. Energy metabolized from body not considered.

energy of the food was only 4,957 calories. Even allowing for a considerable consumption of body fat, the ratio of heat equivalent of work done to total energy of food and body tissue consumed

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must be extremely large. It will be noted that the "work done" is the extreme muscular work, *i.e.*, the mechanical energy applied to the pedals of the wheels.

The figures in the last column of Tables 4 and 5 show the total energy in the food. The values for the individual days are computed by use of factors for heats of combustion of the different nutrients in mixed diet which were proposed by Atwater and Bryant,* which allow 5.65 calories of energy for every gram of protein in the food, 9.4 calories for every gram of fat, and 4.1 calories for every gram of carbohydrates. The average energy in the food for the six days was found by actual determination of the heat of combustion of the foods consumed, but the computations were not made for individual days. The average for the six days of the study is therefore that actually determined, while the amounts for the individual days are computed approximately by use of the factors. By reference to Table 4 it will be observed that the total work done by Miller is computed to have been over 15,000,000 foot-pounds, or 7,500 foot-tons, on the first day, and 5,500,000 foot-pounds, or 2,750 foot-tons, on the last day of the race. The corresponding heat equivalent of the work done is computed by dividing the total number of foot-pounds of work by the mechanical equivalent of one calorie, *i.e.*, 3,088 foot-pounds, and ranges from 4,917 calories on the first day of the race to 1,786 calories on the last day. The average heat equivalent of the work done in the six days amounted to 3,102 calories. At the same time, the food consumed furnished 4,957 calories, making an apparent efficiency of over 60 per cent. It is probable, however, that there was a greater or less consumption of body fat during the experiment, the energy of which should be added to that of the food consumed in estimating the total income, thus diminishing the apparent efficiency. How much this loss of body fat amounted to can not be estimated for the reasons already pointed out (see p. 52). If we assume that the equivalent exposure of the bicycle rider was 4 square feet, computations similar to those recorded in Table 4 serve to show that the total work done each day ranged from nearly 20,000,000 to nearly 7,000,000 foot-pounds, and the corresponding heat equivalent from 6,381 to 2,256 calories, averaging 3,994 calories.

The amount of work done by Albert was slightly less than that by Miller, ranging from 12,000,000 to 4,000,000 foot-pounds per

*Connecticut Storrs Sta. Rpt. 1899, p. 73. These factors differ from those more recently determined.

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day with a corresponding range in heat equivalent from 3,938 to 1,334 calories. The average heat equivalent of the work done per day during the six days is 2,760 calories, and the average energy in the food as found by actual determination of the heat of combustion is 6,307 calories, making an apparent efficiency of nearly 45 per cent. The same uncertainty as to the amount of body fat consumed exists in this as in the previous case, so that we can reach only a very approximate value for the efficiency of the rider. If the equivalent exposure of the rider is assumed as equal to 4 square feet, the total amount of work done each day varied from nearly 16,000,000 to a little over 5,000,000 foot-pounds, with a corresponding range in heat equivalent from 5,088 to 1,686 calories, with an average for the six days of 3,547 calories.

Regarding the probable error of the computations given in Tables 4 and 5 the author is prepared to say but little. The factors determining the wind pressure upon subjects are not definitely known, and the pressure may have been greater or less than that assumed. When one rider followed another it would be less. On the other hand, it is extremely probable that the recorded distance traveled is less than the actual distance, since the riders, much of the time, especially when riding in bunches, were a greater or less distance outside of the "pole" or line which was taken for the measurement of the track. Furthermore, the calculations make no account of increase of work that must have occurred in ascending the slight grade at each end of the course which would be brought about by the travel of the rider on a track some distance from the pole. These conditions should not change the efficiency more than 10 per cent. One thing seems certain; the amount of work performed each day by the riders was very large indeed, and the efficiency appears to have been noticeably greater than that obtained by the best steam or oil engines. The best record of any heat engine is probably that of the Diesel motor. This has produced, in a test by James Denton, 1 horse-power on the brake for a consumption of 0.549 pounds of kerosene oil. This would be equivalent to 3617 heat units per horse-power, the oil being valued at 18,604 heat units per pound; in this case we should have an efficiency of transformation equal to about 25.06 per cent. The best record of a steam engine is the Nordberg pumping engine at Pittsburg, which shows an efficiency per indicated horse-power, on the basis of total heat supplied, of 22.7 per cent. Per delivered horse-power this amount would probably be 10 per cent. less.

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With the exception of the Diesel motor the best record of any oil engine per delivered horse-power is about 16.5 per cent. efficiency.

From this comparison it would seem that the human machine is decidedly superior to any heat engine which has been developed in form so as to be of any value for practical use.

CONCLUSION AND REMARKS.

The calculations would indicate that both Miller and Albert possessed great physical strength and endurance, and that Miller must have been a remarkable physical giant. His results seem unprecedented, especially when expressed numerically. Dr. R. H. Thurston[1] states that the average work of a man is to be considered as about 2,000,000 foot pounds per day, rising occasionally to an amount 50 per cent. greater. Considering 2,000,000 foot-pounds per day as the work of an average man, it will be noted that the energy exerted by Miller during five days of the race was more than five times greater than this amount, and that exerted by Albert was nearly as much. It is quite possible that the calculated results make the energy expended greater than it should be, although a re-examination of the calculations fails to show any reason for reducing the results. It is possible that the wind exposure may have been less than assumed, although it is not believed that the equivalent plane surface could have been less than 2.6 square feet. Had the exposure been as small as this, which is hardly probable, the resistance due to the wind would have been reduced slightly over 13 per cent. The wheel resistance, as previously remarked, may be slightly high. The total of these corrections would reduce the energy expended by about 11 per cent. It is believed, however, that the results given are the most probable.

As before stated, the only accurate measurement of the energy developed by the bicycle riders would be that obtained with a dynamometer applied to the pedal of the bicycle, and at the present time such data are not available.

Most of the data which are published pertaining to the work accomplished by a man relate to the energy which can be applied day after day under usual working conditions and is much less than might be applied when a man was exerting himself to the utmost. Under the conditions of the race the amount of energy exerted can be considered about the limit of human strength and

[1] The Animal as a Prime Mover, Smithsonian Report for 1896.

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endurance. This is reasonably many times greater than would be exerted by the ordinary laborer working under the routine of his usual occupation.

Believing that the additional data regarding the average energy equivalent to the day's work of a man would be interesting, the statement of a few authorities relating to this subject is presented in the following table:

TABLE VI.

POWER OF MEN.

Kind of work.	Foot-pounds per minute for short periods.	Foot. pounds per day (average).	Authority.
Bicycle riding, 10 seconds	19,000		J. B. Denton *a*.
Bicycle riding, 15 seconds	9,080		Do.
Bicycle riding, 96 seconds	8,750		Do.
Bicycle riding, 1 hour	6,000		R. C. Carpenter *b*.
Walking backward and forward on a tilting lever	6,640	3,984,000	Trautwein *c*.
Soldier carrying knapsack (Ruhlman)	5,000	3,000,000	Thurston *d*.
Men raising beetle	4,080	1,224,000	Trautwein *c*.
Climbing stairs for 8 hours	4,032	1,935,360	Welsbach *d*.
Man walking for 10 hours	3,987	2,394,000	Do.
Man lifting heavy hammer 5 hours	3,808	1,142,400	Do.
Pushing on lever in circular path	3,667	2,200,000	Trautwein *c*.
Working on treadmill 7 hours	3,360	1,480,000	Do.
Average work of man	3,330	2,000,000	Thurston *e*.
Raising water with pump	2,400	1,000,000	Trautwein *c*.

a Iron Age, October, 1897, p. 14.

b Sibley Journal, 1899, p. 59.

c Trautwein's Engineer's Pocketbook, p. 607.

d Mechanics of Engineering, 2 (1877), p. 74.

e The Animal as a Prime Mover, Smithsonian Report, 1896.

It is quite generally believed that the amount of energy expended by a laborer is nearly inversely proportional to the length of the working day, taken, of course, with certain limitations. This would indicate that the amount of energy expended during a day of twenty-four hours might be uniform, which is, of course, scarcely ever true.

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TESLA'S ARTIFICIAL LIGHTNING.

HARRIS J. RYAN.

The frontispiece in the present number of the SIBLEY JOURNAL is a reproduction of a photograph recently presented to Dr. Thurston by Mr. Nicola Tesla.

The photograph is a picture of a shower of electrical discharges produced by Mr. Tesla using one of his recent forms of apparatus for studying the production of enormously high electromotive and rapidly alternating electromagnetic actions.

The discharges photographed constitute a collection of huge electric sparks occurring in rapid succession. It is said that the length of the path that these sparks traversed is about 70 feet. It is well known that at high pressures approximately 15,000 volts are required to break down each inch of air at common temperatures and pressures. This amounts to 180,000 volts to the foot. From this we see that the pressure required to produce a 70 foot spark must be about 70 x 180,000, or 12,600,000 volts.

It is perfectly well known to electrical science that with a practical means for the production of such enormous electric pressures there are at hand means for the production and propagation of magnetic impulses that must penetrate to great distances over the earth and be available over such distances either for intelligence or energy transmission.

Mr. Tesla has been an able and persistent investigator along the line in which it is sought to produce the most powerful effects of the character shown by this photograph. Mr. Tesla is preëminently the most successful investigator in this field in the world. He is undoubtedly our greatest authority on actual ways and means for the production of electric discharges at the highest pressures and frequencies.

The principle used by him in all his methods is to transform electric energy in the form of alternating current at ordinary frequencies and pressures to enormously high frequencies and pressures by means of transformers of special construction, in which the self induction and capacities present in and about the circuits of such transformers are so proportioned as to determine the frequency desired on the principle of equating $2\pi f$ and $\frac{1}{2\pi cf}$ and in which the dielectric strength of the media providing the insu-

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lation and requisite capacity are so formed and dimensioned as to withstand the enormous pressures thus to be developed.

Mr. Tesla's one great ambition appears to be to work on in this line until he has found a sufficiently reliable method for the efficient and continuous development of high pressure high frequency currents, after which he would in due course expect to work out a system for the long distance transmission of power, using the universal atmosphere as the medium of propagation of the electrical energy by the transmission of such energy either as dielectric flux or magnetic flux,—details to be decided upon after a satisfactory source of high pressure high frequency current has been provided.

Were it not for this effort on the part of Mr. Tesla he would more actively have entered the field of competition with Marconi and others in developing wireless telegraphy. For nothing can be more certain than that Mr. Tesla, more than any other man living, knows best the ways and means for obtaining the most powerful high frequency high pressure discharges that are required for wireless telegraphy.

The recent numbers of the technical electrical journals announce that Mr. Tesla has made up his mind to take up actively the development of wireless telegraphy. We know that his great powers and vast experience in research in phenomena that are the basis of successful wireless telegraphy will soon enable him to provide the means for telegraphing over greater distances than those over which wireless telegraphy at its best heretofore has been able to transmit.

Dr. Thurston has received a letter from Nikola Tesla, the famous electrician, deferring a hoped-for visit to Cornell and stating that he is engaged in work which cannot now be dropped, the results of which it is expected may soon be published. Accompanying the letter is a photograph of a remarkable scene in the laboratory of the great investigator, showing him at his work, with lightning of his own production flashing across the room on all sides. Professor Slaby has just reproduced this picture in a German technical journal and it is attracting much attention.

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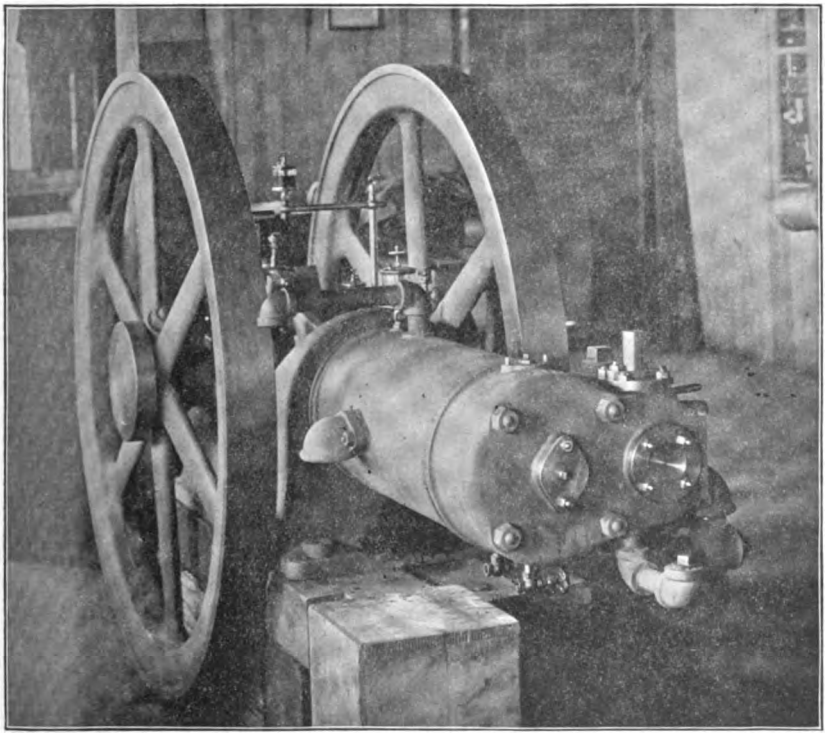
THE NEW SIBLEY GAS ENGINE.

There has recently been completed in the machine shop of Sibley College a gas engine of 16 horse power, from which good results are expected. The castings were furnished us by Mr. George J. Rathbun, M.E., '95, who is connected with the Acme Sucker Rod Co., of Toledo, O. Realizing our limitations in lathes of considerable swing, Mr. Rathbun proposed to have the fly wheels turned and bored before shipping them. By reversing the head stock of a lathe, however, and carrying the tools, on an adjacent lathe, the work was done here. The crank shaft was presented with the compliments of the Titusville, Pa., Forge Co. All the rest of the machine work and fitting and assembling was done in our shops.



The cylinder is 9 inches in diameter, with a stroke of 16 inches. Fly wheels 60 inches diameter, with a face of 4⅜ inches, weighing about 400 pounds each. The main bearings are 4 inches in diameter by 6¼ inches long. The entire engine occupies a floor space of 89 x 58 inches and weighs 4,700 pounds.

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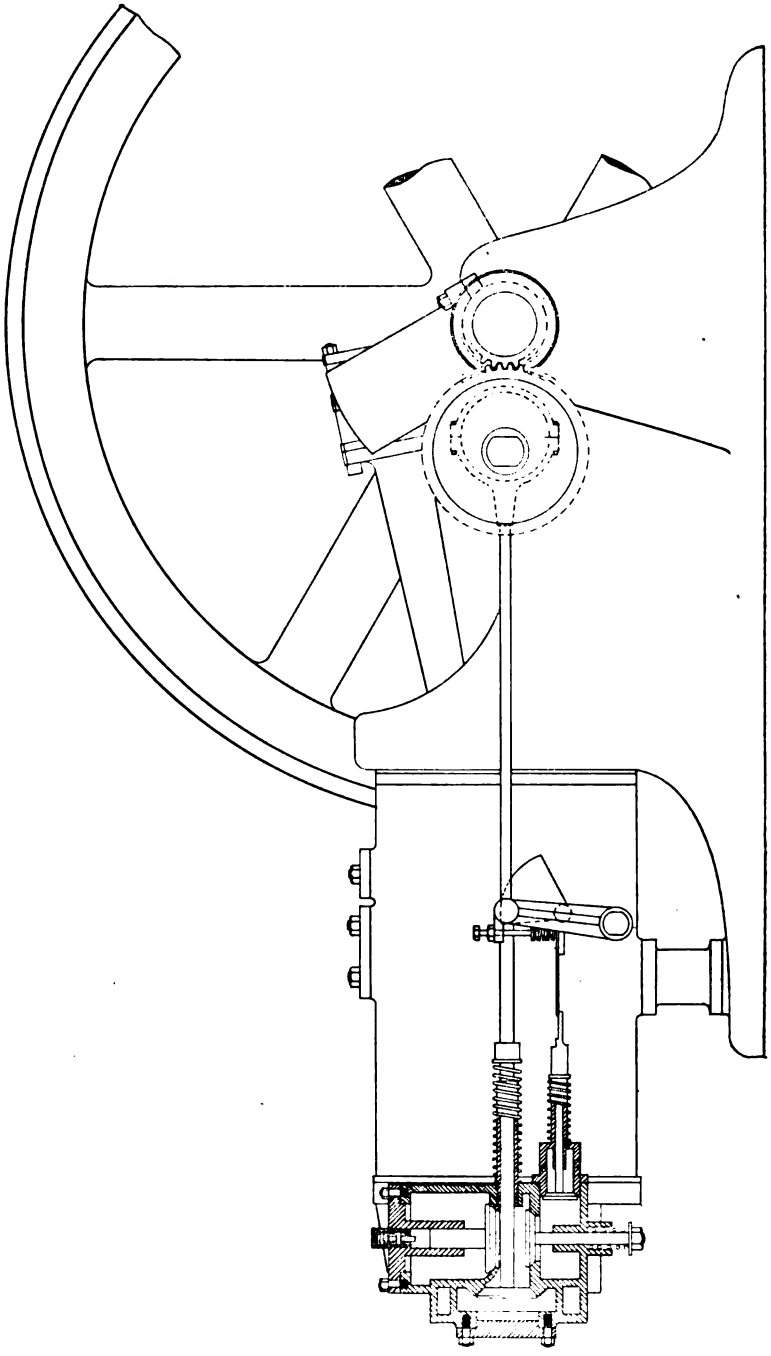

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The accompanying section shows clearly the arrangement of the various valves. It also shows the method taken to obtain one stroke of the valve-stem to two of the crank (for this is a four-cycle engine, working on the Otto cycle). This device consists of two gear wheels the ratio of whose pitch-circles is two to one. The pinion is mounted on the main shaft. On the shaft of the other gear is an eccentric, connected directly with the valve-stem. A former method of accomplishing this same result consisted in the use of a cam, in place of the eccentric, in which case the valve-rod was operated through the medium of a follower.

The ignition is by means of the hot-tube, a feature which is strongly recommended by the Acme Co. as being more economical, more simple, and more easily handled than the electric ignition.

Contrary to the almost universal practice in gas engines, the valve has very little lead. For this reason it will start almost equally well in either direction. The fact, however, that in one direction it has this small negative lead prevents its carrying a load so well when rotating in that direction (running under).

The difficulties in the way of the continued successful operation of a gas engine are due largely to the high temperatures obtained in the cylinder. The exhaust valve is liable to suffer more from this cause than any other part of the engine. Even a liberal water jacket does not seem to be a sufficient preventative against excessive heating. This difficulty is here largely overcome by having the exhaust and entering gases pass through the same valve. The entering gases serve to keep the valve cool, and consequently tight.

The gear is set so that the main valve opens as the piston closes the auxiliary exhaust port at end of stroke, and closes at about the same point. The gas valve opens about three-eighths of an inch, and the governor finger is engaged before the main valve opens. The cylinder head and everything attached to it are entirely independent. The slide on side of cylinder opens the main valve, and carries the governor, which opens the gas valve.

No test of this engine has yet been made, although it has been run experimentally on two or three occasions. It runs very smoothly and ought to show up very well when subjected to a formal test.

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BLUE-PRINTING BY ELECTRIC LIGHT *

S. B. WHINERY, E E., '99.

Because of the difficulty in obtaining blue prints by sunlight in a city like Pittsburg, where conditions are such that for weeks at a time no satisfactory results can be had, innumerable attempts, more or less successful, have been made to use the electric light for printing purposes during dark and cloudy weather.

In most cases, from two to six or eight lamps, reinforced by a parabolic reflector of some easily obtained material, have been used. The poor results usually obtained may be charged largely to the old style open arc lamp and the slow-printing papers, which were used until within the last few years. To meet the demand for a convenient and economical process, two types of machines are constructed; the cylindrical frame, with one movable lamp; and the flat frame, with a number of lamps and a hood reflector.

The standard machine of the cylindrical type consists essentially of a glass cylinder, made in halves and held together by brass bands at top and bottom. It rests on a revolving base, to facilitate loading and unloading. The tracing and sensitized paper are held in place, and good contact secured by canvas covers, which are held tight by means of springs. The lamp, suspended from a bracket directly over the centre-pin of the base, is lowered at a uniform rate by means of a pendulum and escapement gear.

The cylinder is made of the best quality of plate glass, perfectly free from flaws or bubbles. It is first rolled flat and polished, then laid on a semi-cylindrical mould and run into the furnace. As the glass softens by the heat, it sinks into the mould and gradually conforms perfectly to its surface. The half cylinders are then again polished and set up in position, and wooden strips trimmed to fit them rigidly, thus protecting them from cracking by securing an even distribution of strains. The brass bands bind the whole together.

The lamp used with this machine has been especially designed and adjusted for the work and gives a very white light of high

* Abstract of a paper presented before the Engineers' Society of Western Pennsylvania, by S. B. Whinery, E.E., '99.

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actinic power. It is an enclosed-arc constant-current lamp, with exceptionally long arc and correspondingly high potential difference across the terminals. The standard direct-current lamp uses 10 amperes, while the alternating-current lamp requires 15 amperes. An 18 ampere lamp is also used to meet conditions where printing by the standard lamp would be too slow. The standard direct-current lamp on 110 volt circuit consumes about 1.1 kilowatts, giving a candle power of about 2,000. Experience shows that the best effects are obtained with the positive carbon on the bottom. The motion of the lamp is almost uniform.

The modern flat frame type uses an ordinary sun printing frame, and General Electric Co.'s standard 110 volt lamps, which give a very even light of about 1,000 candle power, on a consumption of about 5 amperes, or 550 watts. Approximately one such lamp is used for 4.8 square feet of printing surface, the light being concentrated on this surface by means of a sheet-iron hood of parabolic form, coated with white enamel

The cylindrical machine requires the minimum amount of floor space and uses less current. Allowing 2½ minutes per print, the cylindrical type uses 10 amperes to make two prints, or 12½ ampere-minutes each. The flat frame type, with four lamps, requires 20 amperes and makes one print, at a cost of 50 ampere-minutes. The flat frame type is somewhat the cheaper of the two, in first cost, but will make twice as many prints per day. The contact between tracing and print is practically perfect with the cylindrical machine, which is not the case with the flat frame. On account of carbon cost and breakage of shades, the cost of maintenance is greater for the flat frame type, and it also requires more time per print; but it is available for sunshine-printing whenever the power fails.

As to economy—with power at 12 cents per kilowatt-hour, it is found that for the average sizes of prints the flat frame will give 57 per day, at an average cost of 2.09 cents each; the cylindrical frame 236 per day, at a cost of 1.14 cents each; while the sun gives 42 prints at a cost of 2.39 cents each.

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Dr. A. E. Kennelly gave on Nov. 1st, a most interesting and systematic treatment of electrical switching devices in the course given before Sibley College by non-resident lecturers. He traced the history of the electric switch from a primitive wire loop hooked loosely across simple wire terminals to the complicated mechanisms used at the present time for opening circuits of enormous current and pressure capacities.

Dr. Kennelly called attention to the fact that the character of installation is clearly indicated by the form of switching devices used and he illustrated this point by a series of pictures showing in what different forms the switch appears when adapted to meet different requirements. Among the most interesting forms of switch were the modern oil-immersed switches for extremely high tension service. It was stated that these switches would break a circuit carrying a high tension current without any appearance of an arc. A switch of this kind can open with perfect ease a circuit which is carrying as much power as is represented by two Empire State express trains travelling at velocities of 75 miles an hour, and that instantly.

An idea of the enormous pressures which have to be handled in modern power transmission work was given by showing reproductions of photographs of the arcs accompanying the opening of such circuits with moderate currents flowing. The effect is spectacular in the extreme, the whipping arc being drawn out for a length of several feet. By the means of proper devices these arcs can be, and are, entirely eliminated and a 60,000 volt pressure circuit can be opened without any great manifestation of the enormous power involved. The lecturer stated that formerly it was customary to employ two men to open high tension circuits, the function of one being to open the switch while that of the other was the dangerous performance of "batting" out the arc. One noticeable feature of all of the modern switches for opening high tension circuits is their extreme simplicity, the main endeavor being to obtain a long break, with safety to surrounding apparatus and to the attendants. The switches for manipulating circuits of large current carrying capacity at moderate pressures were seen to be much more complicated in mechanism on account of the massiveness of the parts and of the mechanical force necessary to operate them. The various devices used for enabling the operator to handle the switches with ease and yet at the same time to make perfect electrical contact, consist of levers, toggle-joints, laminated switch blades and in some cases hydraulic pistons or electric

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motors. The latter allow of control from a distance and the switch proper may be located in a comparatively inaccessible position, while the controlling device may be placed wherever it will be most convenient. As an illustration of this a picture of a small distant-control switch-board table was shown from which one operator can very conveniently handle a large number of heavy current circuits with a maximum of convenience.

Dr. Kennelly described one danger in the handling of large alternating currents, especially in the opening of heavy overloads or short circuits. If L is the inductance of the circuit, the energy stored in the medium about the circuit is

$$W = \frac{1}{2} L I^2$$

and this energy must be dissipated while the switch is being opened. If the operator happens to open the switch when the current is passing through zero no trouble can result, but if the circuit is broken when the current is at or near maximum, its potential energy is very great. The only possible disposition of this energy after the circuit is open is in the electrostatic form, represented by

$$W = \frac{1}{2} C E^2,$$

where C is the capacity of the circuit and E is the pressure corresponding to the amount of energy electrostatically stored in the circuit. As the potential energy of the circuit before opening may be equal to the potential energy after opening, it is apparent that in circuits of large inductance and small capacity the pressure generated will be dangerously high, amounting to many times the normal circuit pressure. This effect must be distinguished from that known as resonance in which the reactance due to inductance and capacity balance at a certain frequency and hence give rise to enormous local pressures.

Dr. Kennelly closed his lecture with the suggestive remark that the sentiment behind the famous expression, "the man behind the throttle," now applies with equal force to the significant words, "the man behind the switch."

HENRY H. NORRIS.

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The Motor World, in referring to the recent automobile run from New York to Buffalo says :

The work of the four White carriages caused more talk than anything else on the run. Their striking snow white finish compelled attention from the very start, and as the run wore on they proved themselves as good as their looks. Before the run was half over their performances gave "steamer" stock and water tube boilers a boost that put the gasolene vehicles on their mettle. If they gave trouble, the fact was remarkably well concealed, and in justice it must be said that there is not the slightest evidence of such a thing. A punctured tire, a buckled wheel, a bent rear-spring—due to a rear end collision—these constitute practically the sum of the mishaps.

Asked at Rochester what he thought this remarkable showing was due to, one of the operators stated that two things were responsible, viz., the principle upon which the boilers were made and the remarkably high character of the workmanship and material entering into the construction of the vehicles.

"The new flash boiler, invented and patented by Mr. Rollin H. White,"* he said, "is the greatest departure from the regulation steam vehicle construction, and to it the chief merit belongs. It is constructed on the same principle as the gas water heaters now in use in houses. The water passes through pipes or tubes, entering them cold and emerging quite hot. The heating is almost instantaneous, the conversion into steam almost equally rapid. The quantity of steam that can be generated is much larger than usual, being limited only by the amount of water that will pass through the tubes in a given time.

"The advantages of this system will be readily understood. There is no boiler incrustation, no frequent cleaning required or other troubles incident to the ordinary boiler caused.

"In the building of these vehicles, too, the most extraordinary care has been exercised. Skilled workmen who have been steam engine fitters all their lives have been employed, and the result has been a well-nigh perfect steam vehicle."

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* M.E., Cornell, 1894.

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L'Industrie Automobile, in discussing the net cost of the horse-power-hour with varying motive powers, gives the following results translated into American units:—

A man, exerting an average effort of 15 pounds on a winch of 14 inches radius, works 8 hours at a speed of 30 r.p.m. The price of the working day being 68 cents (in France), the horse-power-hour will cost **81 cents.**

A horse weighing 1100 pounds, attached to a gin of 13 feet radius, exerts a force of 120 pounds at the rate of 180 feet per minute for 8 hours. The day of the horse being valued at 77 cents, the horse-power-hour will cost **19 cents.**

An ox, working under the same conditions, exerts a force of 145 pounds at the rate of 130 feet per minute. The price of the day being 68 cents, the horse-power-hour will cost **22 cents.**

A steam engine of 3 to 8 horse power, costing from $150 to $200 per horse power, consumes about 6.5 pounds of coal per horse-power-hour. The net cost of the horse-power-hour is here about **4 cents.**

A windmill of ¼ to 3 horse power, costing from $200 to $600, furnishes one horse-power-hour for **2 cents.**

A petroleum motor consumes one-half to four-fifths of a quart of petroleum or gasoline per horse-power-hour and costs $120 to $160 per horse power. The net cost of one horse-power-hour may be placed at **7 cents.**

A water wheel, costing from $80 to $160 per horse power, makes the cost of the horse-power-hour come to **.01 cent.**

A turbine, costing from $20 to $100 per horse power, gives substantially this last result.

The Binghamton Republican refers to the report of the Engineer-in-Chief of the U. S. Navy, Rear-Admiral Melville, in which it is intimated that the provisions of the "personnel bill" are not fully carried out on board ship in the drill of young officers with a view to securing efficiency and reliability in engine-room service as well as on deck. It is asserted that it is the man at the engines and the boilers, rather than the man behind the gun, who makes or mars the success of the war vessel, and that the whole great engine of war is purely a machine of which the efficiency depends fundamentally upon the efficiency of the engineers and mechanics and the men in the fire-rooms. The man behind the gun could not get his opportunity were the ship not

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properly handled at the source of power and even the operation of the guns is a sort of engineering.

It is now, according to this authority, an evident error to permit the efficiency of the Navy to be endangered by the endeavor to convert into an expert in engineering, the amateur of another profession and to teach him two trades or more ; especially as he is not self-elected to his proposed vocation. Only naturally well-fitted and natural mechanics, the man with a genius for mechanism and engineering, should be placed in such a position of supreme responsibility. It is suggested by our contemporary that the technical schools of the country should supply this class of naval officers as they have actually done at an earlier date, when they provided the service with a class of young men who have never been equalled, as talented, professionally educated and efficient officers. The Naval Academy, however, under the stimulus of this need and the encouragement of its departments by the Secretary of the Navy, has come to be admirably adapted for instruction in a similar curriculum and the young officers there under instruction are now given more scientific and engineering instruction than in any other field, and the conversion of the U. S. Naval Academy at Annapolis into a high-grade technical school seems likely to occur as rapidly as the entrance requirements can be suitably elevated.

At the convention of the New England Cotton Manufacturers' Association, held at Niagara Falls, on Sept., 25, the president Mr. Charles H. Fish, said, in his opening address :

"The ideal cotton manufacturer of the future, and I may say of to-day, is one who not only understands the art of spinning and of weaving the cotton fibre, but is also proficient, at least to some extent, in the different branches of engineering. He must understand excavations, foundation work, and construction of all kinds. He must be able to figure for himself the strength of materials. He must be able to estimate the power required, and the power consumed. He must know the water-wheel, the steam engine, and the application of gas, compressed air, and electricity ; and so it is that the cotton manufacturer must also be, in a way, a mechanical engineer, an electrical engineer, and I believe in most localities a knowledge of political engineering will not come amiss.

" In following out this thought, I will recommend most strongly the fostering of our technical and textile schools and colleges,

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and the encouraging in every way possible the boys and young men in our factories, giving to them opportunities for study and investigation, not only in the line of cotton manufacturing, but also in the different branches of mathematics and engineering."

"MACHINERY" for October, in discussing the remarkable development of our steel industry during the last decade, after comparing our 1900 products with those of Great Britain and Germany says:

"Twelve years ago as good an observer of industrial conditions as Mr. William Kent, made the prediction that even with equal labor conditions the United States could not hope to compete with England and Belgium in the metal markets of the world, owing to the disadvantageous locations of our coal and iron fields with respect to the centers of industry. As a matter of fact we *are* competing successfully for the 'markets of the world', owing to the improved methods adopted in this country. What these improvements have been were hinted at by Mr. Kent in a lecture given before the students of Sibley College last year, when, in referring to his previous prophecy he said:

'I was a poor prophet, but who could have foreseen eleven years ago that the Mesaba iron ore range would be discovered, and that its ores would be mined with a steam shovel; that railroad cars filled with ore would be lifted bodily and their contents transferred directly into the hold of a vessel; that 6000-ton ore vessels would be built to carry the ore on the lakes; that a railroad could be built from Lake Erie to Pittsburg with ore cars of 100 tons capacity each; that these cars would be unloaded without manual labor, and that the barrows in the ore bins would be loaded automatically and in like manner dumped into the furnace? Who could foresee that the geographical disadvantage would be removed by improved methods of transportation?' "

The production in 1900, in round numbers in tons, was given as follows:—

	United States.	*Great Britain.*	*Germany.*
Coal	238,900,000	225,200,000	149,600,000
Iron Ore	26,000,000	22,800,000	19,300,000
Pig Iron	13,800.000	8,000,000	8,400,000

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THE SIBLEY JOURNAL OF ENGINEERING,

ITHACA, N. Y.

We take pleasure in announcing the selection of Mr. Ralph G. Young, as Graduate Editor of the SIBLEY JOURNAL. Mr. Young graduated with the class of 1901, in the Course of Electrical Engineering, and is now working for his M.M.E. He was recently appointed assistant in the Mechanical Laboratory.

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Obituary.

Edgar Percival Seeger, '98, died at the Ithaca Hospital on Sunday, Nov. 3, at 4 P. M. His death was caused by blood poisoning that resulted from a pin scratch on the face.

Mr. Seeger was born Nov. 8, 1875, at Watertown, Wis. He entered Sibley College as a student in Electrical Engineering with the class of 1898, having received his preparation at the Chicago Manual Training School. He was a member of Phi Kappa Psi Fraternity, Sphinx Head and Aleph Samach. At the close of his Junior year he was elected Editor-in-Chief of the SIBLEY JOURNAL, which he conducted most successfully during his senior year.

Immediately after graduation he accepted a position as Assistant to the Superintendent of the Carborundum Company at Niagara Falls. Later he entered the employment of the Westinghouse Electric and Manufacturing Company at Pittsburgh, having recently been appointed to a position on their corps of Erecting Electrical Engineers.

In May of the present year he was detailed by his Company to erect the electrical machinery for the new equipment of the Remington Salt Works at Ithaca.

Mr. Seeger was an enthusiastic Cornellian with a personality that won devoted friends everywhere. He was strong physically and mentally. His Alma Mater mourns the loss of one of her most promising sons.

Department Notes.

Last year the Electrical and Mechanical Societies exchanged their combined Proceedings with the Association of Engineering Societies of the University of Illinois. The Proceedings of the latter, called the "Technograph", is an attractive volume of 152 pages, containing some twenty papers relating to Electrical, Mechanical, and Civil Engineering, and to Architecture.

Dr. Thurston has been requested to act upon one of the Visiting Committees of Brown University, his Alma Mater, by President Faunce. He will presumably give special attention to the scientific and engineering departments. He has also been asked, as a foreign member of the Swedish Royal Academy of Sciences, to

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act with the committees entrusted with the recommendation of recipients for the Nobel prizes for the greatest scientific work of the past year. The other American members of the Academy are Messrs. Simon Newcomb, and Thos. A. Edison.

The lists of nominations of candidates for appointment at the coming annual convention of the American Society of Mechanical Engineers has been issued to members for consideration. It is not permitted to give names, as these are confidentially submitted for a vote ; but it is permissible to state that on these candidates, four Cornell and Sibley College men are candidates for full membership by appointment, three by promotion. Two are candidates for associate membership, six for junior membership, to which grade all graduates are eligible immediately upon receiving their diplomas. Fifteen per cent. of the candidates for this grade on this list are Cornell and Sibley College men. No other institution approaches this proportion. In the list of proposed associates, twenty-five per cent. are from Sibley College and none from any other institution of the class. In the proposed promotions to full membership, forty-five per cent. are Cornell men, in M.E., and no other institution has more than one candidate ; of all candidates for admission to full membership, the percentage is a trifle above ten. The full list, in all grades, numbers one hundred and fourteen, an unusually large accession.

SIBLEY COLLEGE LECTURES.

(Provisional dates, subject to change).

November 1st, 1901.—A. E. Kennelly, Ph.D., Electrical Apparatus.

December 6th, 1901.—W. B. Potter, Engr. General Electric Co., Development of the Electric Locomotive.

December 13th, 1901.—Wm. Kent, M.E., Engineering in Mexico.

January 17th, 1902.—Chas. Kirschoff, M.E., The Commercial Side of Engineering.

January 24th, 1902.—D. L. Cease, R. R. Trainmen's Association, Employers and Employees.

February 7th, 1902.—F. A. Halsey, M.E., (C. U.), The Premium Plan.

March 21st, 1902.—A, J. Wurts, M.E., The Nernst Lamp.

April 11th, 1902.—P. B. Delaney, Applied Electricity.

May 9th, 1902.—W. M. McFarland, U. S. N. A., Steam and Electricity.

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Personals.

'78. Ben Johnson, has been appointed Superintendent of Machinery of the Mexican Central Railroad, with headquarters in the City of Mexico. This, the principal railroad in Mexico, is the only standard-guage road reaching the capital.

'92. Calvin Henry Crouch, M.E., who was last year with the Baldwin Locomotive Works, in Philadelphia, is now instructor in Mechanical Engineering, at the University of North Dakota.

'96. George K. Woodworth, E.E., is connected with the Patent Office, in Washington, D. C.

'97. Lester H. Lewis, E.E., is with the General Electric Co., of Schenectady.

'98. William B. Shafer, Jr., is in the employ of James Beggs & Co., of New York City.

'99. Samuel Brent Whinery, E.E., an abstract of whose paper on "Blue Printing by Electric Light", read before the Engineers' Society of Western Pennsylvania, we publish elsewhere in this issue, was first employed, after graduation, in the testing department of Westinghouse, Church, Kerr & Co., at Pittsburg. Later he was located with the Westinghouse Machine Co., engaged in installing new machinery in their foundry. A few months ago, he entered the employ of the Pittsburg Blue-Printing Co. His work here laid the basis for his paper, which was very well received.

'99. E. M. Kinney, M.E., and William Gordon, E.E., are with the General Electric Company.

'00. Austin Burt, M.E., is manager of the Cedar Falls Light, Heat and Power Co.

'00. John V. McAdam, M.E., is with the Shickle, Harrison and Howard Iron Co., of St. Louis, Mo.

'01. Howard W. Riley is with the United Telephone Co., of New York City.

'01. Clifton B. English, M.E., is in the cement business at Easton, Pa.

Ex.-'01. Eugene A. Kinsey, M.E., is in the employ of The Locomobile Company, of Buffalo, N. Y.

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BOOK REVIEWS.

Revue de Mécanique. Published under the patronage and technical direction of a board of editors composed of M. Haton de la Goupillière, President, and twelve associates. Vve. Ch. Dunod, publisher, Paris, 1901. Annual subscription price, 40 francs.

May: Study of the Steam Engine by the entropic diagram, continued, Air Brakes, continued; Elementary Geometry of Thermodynamics, from Dr. R. H. Thurston, in "Journal of the Franklin Institute."; Lathes, turret and otherwise; Boilers and Engines for Superheated Steam; Review of Periodicals and Patents.

June: Condensers and Air-pumps; Purification of Blast Furnace Gases; Methods of Assembling in the Construction of Water-tube Boilers; Review of Periodicals, Inventions and Patents.

July: On the Laws of Expansion and Compression in the Steam Engines by Dwelshauvers-Dèry; Safety appliances in Steam Boilers; Gas Engine, for Blast Furnaces; Allis 8000-H.P. Engines in New York City; Trial of a Parsons Turbine in Sibley College, by F. E. Cardullo—from SIBLEY JOURNAL, June 1901; Trial of a 1000-H.P. Gas Engine with Compressor,—from SIBLEY JOURNAL, June 1901; Review of Periodicals, Inventions and Patents.

August: Test of a 500-H.P. Steam Engine; Supplement to the Theory of Hydraulic Brakes; Study of Hydraulic Propulsion,—Theory and Practice; Rules Established by the *American Society of Mechanical Engineers* for the trials of Steam Engines; Review of Periodicals, Inventions and Patents.

How to Become a Good Mechanic. By JOHN PHIN. Published by the Industrial Publication Co., New York, 1901. 68 pp. Paper 25 cents.

This little work, aimed to help youths who, from necessity or otherwise, enter the trade of a mechanic, contains much wholesome advice and suggestion. The advisability of a "home-made" education is brought before the reader in such a way as to command attention.

Electromagnets; their Design and Construction. By A. N. MANSFIELD, S.B. Published by D. Van Nostrand Co., New York, 1901. 155 pp. 50 cents.

This little work takes up in comprehensive form the general theory and construction of the electromagnet, developing formulae for values of flux, permeability, tractive force, etc., without the use of the calculus. 36 diagrams are used to illustrate and explain the text, while a number of valuable tables add to its value as a reference book.

A B C of the Telephone. By JAMES E. HOMANS, A.M. Published by Theo. Audel & Co., New York, 1901. 12 mo. xvi + 332 pp. 268 illustrations. Cloth, $1.00 post-paid.

This treatise on the construction, installation, and operation of the telephone and its appliances, is divided into 28 chapters, treating of the theory of sound, electrical principles relating thereto, the various parts of a telephone and of telephone service, switches and shunts, line construction, protective devices, automatic exchanges, and a variety of other items of importance in telephone work. Written in an easy style, it would readily appeal to a non-technical reader; while the quantity and quality of the matter presented, and the many sides from which the subject is approached, would commend it to any one interested in this important branch of the electrical industry.

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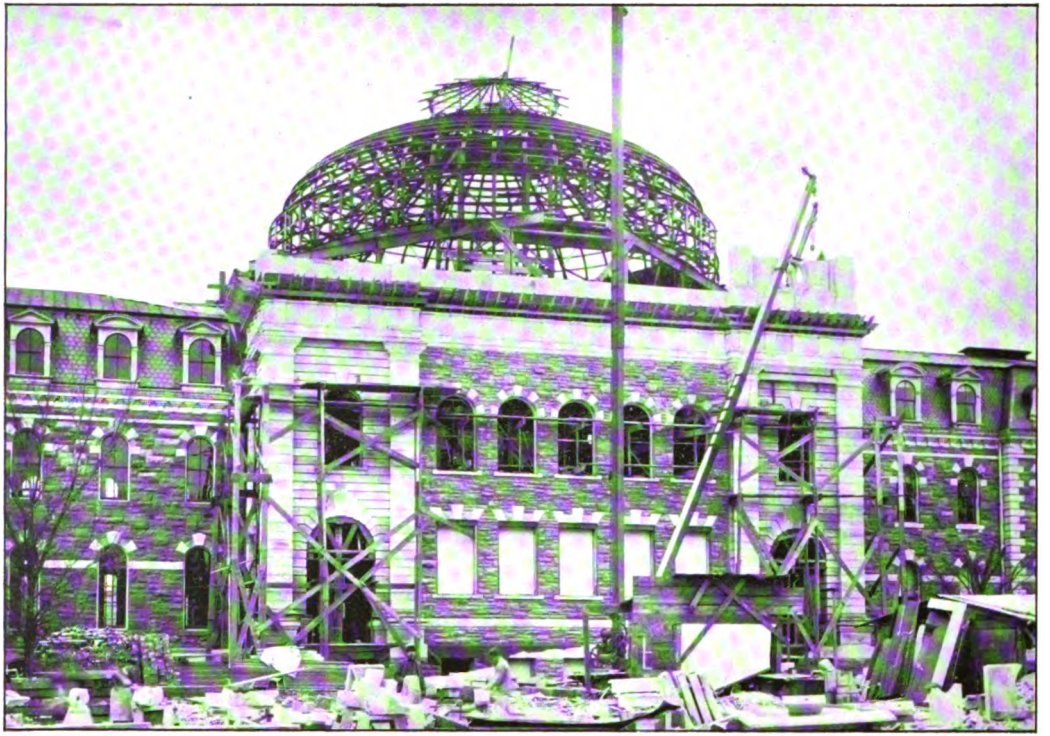

SIBLEY COLLEGE, DEC. 3, 1901.

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THE SIBLEY JOURNAL OF ENGINEERING.

VOL. XVI. DECEMBER, 1901. No. 3.

IN CORNELL UNIVERSITY.

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislature of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

A DIAGRAM FOR DETERMINING THE WORKING STRESS IN METALS, WITH VARIABLE LOAD.

JOHN H. BARR.

It has been found by general experience and special experiment that materials which are subjected to continuous variation of load, cannot be depended upon to resist as great stress as the same materials will bear if the load is applied but once, or only a few times. It appears that the breaking strength under variation of stress, or the "carrying strength", is a function of the number of repetitions and of the range of the stress. The allowable working stress depends upon: (a) The number of applications This should be considered as indefinite, or practically infinite, in most machine members. (b) The range of stress. This is frequently from zero to the maximum; or it is frequently between equal plus and minus values. (c) The static breaking strength or the elastic strength of the material.

The theory of this subject is, as yet, too incomplete to permit of derivation of rational formulas which express the relations between the carrying strength and the static breaking strength under continuously varying stress. All formulas that have been derived for computations of the carrying strength under repeti-

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tion of live load are empirical ones which have been adjusted to conform, more or less closely, with experimental observations.

Two formulas which have been quite commonly accepted, are: Launhardt's for varying stress of one kind only; and Weyrauch's for stress which changes sign during the variation, *e. g.*, from tension to compression. Professor J. B. Johnson has derived a single formula to cover both of these cases. His expression is obtained by certain modifications of the two above named formulas; and the justification for these modifications is given in Johnson's Materials of Construction, pages 545–547.

The scope of the present paper does not permit discussing the general question of repeated stress, for this article is only written to present a graphical representation of the Johnson formula. It is thought that this diagram offers a convenient means of solving such problems (within its range) as would otherwise be solved by substitution in the formula. Somewhat similar diagrams might be based upon other formulas for carrying strength.

Let P = maximum total load on the member.

P' = minimum total load on the member.

p = the maximum intensity of stress, corresponding to load P.

p' = minimum intensity of stress, corresponding to load P'.

U = ultimate intensity of static stress, or static strength of the material.

u = safe intensity of stress under dead load $= U \div m$, when m is a suitable real factor of safety to provide for contingencies, such as defects of material and workmanship, overloading, etc.

Then, according to Johnson's formula, for breaking loads,

$$p = \frac{\frac{1}{2} U}{1 - \frac{1}{2} \frac{p'}{p}} = \frac{\frac{1}{2} U}{1 - \frac{1}{2} \frac{P'}{P}} \qquad (1)$$

for safe working loads,

$$p = \frac{\frac{1}{2} u}{1 - \frac{1}{2} \frac{p'}{p}} = \frac{\frac{1}{2} u}{1 - \frac{1}{2} \frac{P'}{P}} \qquad (2)$$

In the general problem of design the section of the member is to be found, the loads upon it being known or assumed. In this case p and p' are not known, but the *ratio* of $p' \div p$ is the same as the ratio of $P' \div P$; hence the latter ratio can be used in the denominators of eqs. (1) and (2), as indicated.

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In the common method of designing on the basis of the static breaking strength of the material, a large factor of safety is used with live loads, since experience has shown this to be necessary. If the true carrying strength is determined for the actual conditions of variation of stress, it appears that the factor of safety for contingencies, or the real factor of safety, need not be greater than with dead loads; provided the actual maximum load is equally determinate in both cases. If the stress varies continuously between equal and opposite values (as in car axles), the carrying strength appears to be only about one-third the static breaking strength; that is, a material which would break under a stress of 60,000 lbs. per square inch by a load gradually applied, would break under an indefinite repetition of stress varying between about 20,000 lbs. tension and 20,000 lbs. compression per square inch. It thus appears that the working stress under this complete reversal of load should be only one-third the working stress under dead load. If, in this latter condition, a *real* factor of safety of 3 is necessary to avoid straining beyond the elastic limit and for contingencies, the reversal of load would call for a common factor of safety of $3 \times 3 = 9$. Thus, remembering that shock is more liable with live load, the common factors of safety of 10 or 12 in machine members do not provide much, if any, greater margins for contingencies than do the factors of 3 or 4 with dead loads. While the large factors of safety used when machine parts are designed on the basis of static breaking strength may be explained in this way; it is evidently more satisfactory to determine, as closely as may be, the carrying strength under the actual conditions and then to use a moderate contingency factor, or *real* factor of safety.

If eq. (1) be accepted as giving the ultimate carrying strength under load varying from P' to P; it follows that eq. (2) will give the maximum working stress, under similar variations, for a real factor of safety, or contingency factor of m; m being 2, 3, 4, or whatever may be deemed advisable.

In substituting in eq. (1) or (2), care must be taken to use the proper signs; thus, if tension is taken as positive, compression must be taken as negative; or, if stress varies between tension and compression, P is positive and P' is negative.

From eq. (2):

(I). For dead load, $p' = p$, or $P' = P$; hence the maximum safe unit stress is:

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$$p = \frac{\frac{1}{2}u}{1 - \frac{1}{2}\frac{P}{P}} = \frac{\frac{1}{2}u}{1 - \frac{1}{2}} = u. \qquad (3)$$

(II). For repeated load,* from zero to maximum load, $p' = 0$, or $P' = 0$; hence the maximum safe unit stress is:

$$p = \frac{\frac{1}{2}u}{1 - \frac{1}{2}\frac{0}{P}} = \frac{\frac{1}{2}u}{1 - 0} = \frac{1}{2}u. \qquad (4)$$

(III). For reversed load, between equal and opposite values, $p' = -p$, or $P' = -P$; hence the maximum safe unit stress is:

$$p = \frac{\frac{1}{2}u}{1 - \frac{1}{2}\frac{-P}{+P}} = \frac{\frac{1}{2}u}{1 + \frac{1}{2}} = \frac{1}{3}u. \qquad (5)$$

The cases above (I, II, and III) are very frequently approached in practical cases. It is convenient to remember that the approximate relative carrying strengths may be assumed as 1, ½, ⅓ for cases I, II, III, respectively; though the relation is derived from a general empirical formula and hence is not to be considered as exact in any particular case.

If the minimum load is equal to, say, .6 the maximum load and is of the same sign, $P' = .6P$; hence the safe maximum stress is

$$p = \frac{\frac{1}{2}u}{1 - \frac{1}{2}\frac{.6P}{P}} = \frac{\frac{1}{2}u}{.7} = .714u.$$

If the minimum load is numerically equal to .4 the maximum load, but of opposite sign, $P' = -.4P$; hence the maximum safe unit stress is:

$$p = \frac{\frac{1}{2}u}{1 - \frac{1}{2}\frac{-.4P}{+P}} = \frac{\frac{1}{2}u}{1 + .2} = .417u.$$

In a similar manner, the maximum safe intensity of stress can be readily computed for any range of load.

The diagram facing this page is a graphical expression of equation (1) It affords a means of determining, without numeri-

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*The term "repeated load," when used without qualification, means load entirely removed and applied; or $P' = 0$. The term "reversed load," when unqualified, means minimum load equal and opposite to the maximum load; or $P' = -P$.

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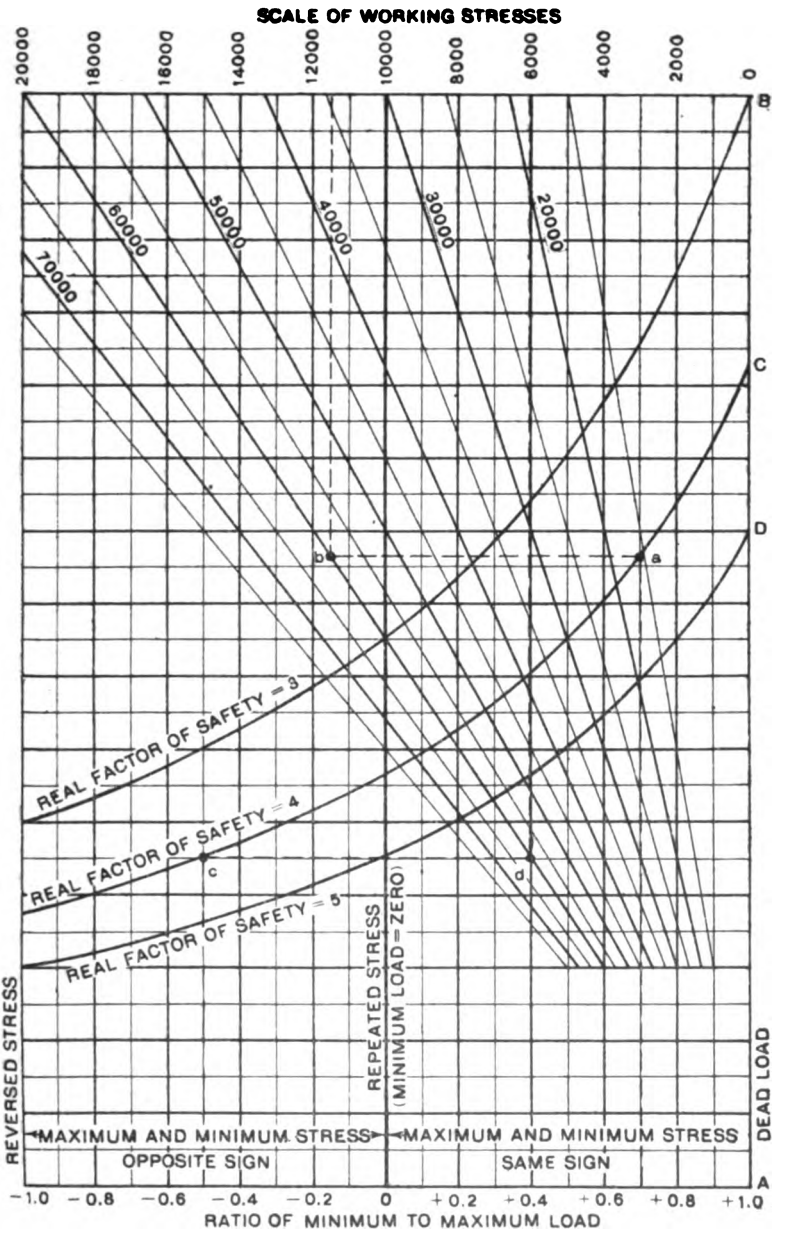

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cal computations, the safe working stress for any range of load between $P' = P$ and $P' = -P$, with materials of from 15,000 to 75,000 ultimate static strength, and with real factors of safety from 3 to 5. This diagram is constructed as follows: The abscissas are the ratios of the minimum to the maximum loads, *i. e.*, $x = P' \div P$. The vertical distance $A \cdot\cdot B$ represents u, the safe static unit stress for any material, when a real factor of safety of 3 is employed. The ordinates of the curve which extends downward and to the left from B represent the maximum safe stresses corresponding to various values of $P' \div P$, when $A \cdot\cdot B$ represents the ultimate static strength divided by 3. In other words, the ordinates of this curve are proportional to the safe carrying strengths, for a real factor of safety of 3, with various ratios of P' to P.

In a similar way, $A \cdot\cdot C$ represents the safe static unit stress with a real factor of safety of 4; hence $A \cdot\cdot C = \frac{3}{4}(A \cdot\cdot B)$. The vertical distance $A \cdot\cdot D, = \frac{3}{5}(A \cdot\cdot B)$, represents the safe static unit stress for a real factor of safety of 5.

In order to readily determine the safe maximum working stresses for materials of different ultimate strength, the diagonals are drawn; each corresponding to the designated ultimate strength. The upper scale, along the horizontal line through B, is the scale of working stresses.

The use of the diagram will be illustrated by examples. Suppose that the minimum load is .7 of the maximum load and of the same sign; that the ultimate strength of the material is 60,000 lbs. per square inch, and the real factor of safety is to be 4. Since $P' \div P = x = .7$, pass from .7, on the lower horizontal scale, vertically upward to point a on the curve for a real factor of safety of 4; then pass horizontally (to the left in this case) to the point b on diagonal marked 60,000; then vertically to the upper scale, where the safe working unit stress is read as 11,600 lbs. per square inch, approximately.

For another illustration, take $P' = -.5\,P$, (minimum and maximum stresses of opposite sign), the real factor of safety and ultimate strength being as before. Then $x = P' \div P = -.5$, and from the corresponding point in the lower scale pass upward to the point c on the curve for a real factor of safety of 4; then horizontally (to the right, in this case) to the point d on the diagonal marked 60,000; then pass upward to the scale at the top of the diagram, where the working unit stress is read as about 6,000 lbs. per square inch. The general method is to start on the lower horizontal scale at a point corresponding to $x = P' \div P$; pass

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vertically upward to the curve corresponding to the appropriate real factor of safety; pass horizontally to the diagonal corresponding to the ultimate strength of the material; then pass upward to the scale at the top of the diagram, where the maximum working stress is read off. This maximum working stress, in connection with the maximum load, affords the data for determining the section of the member by the ordinary formulas of mechanics. For example, assume that a shaft is subjected to a twisting action varying from 90,000 inch lbs. right handed moment, $M = Pr$, to 40,000 inch lbs. left handed moment, $M' = P'r$,

$$\therefore P' \div P = x = -4 \div 9 = -.444.$$

Also assume that the ultimate shearing strength of the material is 40,000 lbs. per square inch, and the real factor of safety is 3. From the diagram the maximum safe unit stress (p) is found to be about 5,600 lbs. per square inch. But in case of torsion,

$$M = Pr = \frac{\pi}{16} d^3 p,$$

$$\therefore \quad d^3 = \frac{90{,}000 \times 16}{5{,}600\,\pi}, \text{ and } d = 4.34'', \text{ nearly.}$$

The diagonal lines are located as follows: With a factor of safety of 3, the safe working unit stress under a dead load is $\frac{1}{3}$ of the ultimate strength; the safe unit stress for a material of 30,000 lbs. strength will be 10,000 lbs., etc. Hence, as the point B corresponds to a dead load with a factor of safety of 3, and as the diagonals cut the safe stress scale in a horizontal through B, each ultimate strength diagonal must cut this horizontal at a distance to the left of B corresponding (as read on the safe stress scale) to $\frac{1}{3}$ this ultimate strength. The 30,000 diagonal intersects the safe stress scale at 10,000; the 45,000 diagonal intersects at 15,000, etc.

In default of more exact data, which may be obtained by actual tests of the material to be used, the following general values may be taken for the ultimate strengths of the specified metals under the various kinds of stress:

	Tension.	*Compression*	*Shearing.*
Bessemer or Open Hearth Steel—(Machinery, or mild steel)	60,000	50,000	48,000
Wrought Iron Bars	45,000	40,000	35,000
Steel Castings	45,000	------	------
Cast Iron	16,000	90,000	12,000
Bronze	30,000	------	------

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THE PRESIDENT'S MESSAGE.

The President's annual report to the Board of Trustees of the University has been presented, printed and distributed to the alumni of the University, so far as the addresses of living alumni were known to the University authorities. Those who have not seen the report may assume that their addresses are not in the lists of the alumni at hand, and should at once supply the missing addresses and apply for copies of this most important document which annually issues from the University press.

A very brief abstract, as usual, can only be given here, with equally brief comment:

The report opens with a statement of the changes which have occurred in the list of officers of the University and an account of the life and work of the new men. A plea is made for provision for a system of pensions for retiring professors, both as matter of justice and as aiding in the retention of able men who otherwise, as has actually occurred, may accept calls elsewhere as an insurance against loss of income when retiring.

Attention is called to the fundamental principle that the good name of the University should not be permitted to suffer through thoughtlessness and lack of fine moral sense on the part of a small minority of students. It is advised that discipline should be made uniform in method and effect by conferring the duty of supervision in such matters on the University Faculty. Both the college faculties and the Trustees promptly acted; the suggestion was at once adopted, and the University Faculty has now appointed "a Committee on Conduct." It is further suggested that further action may be required, particularly, in prevention and cure of that standing, but fading, disgrace, fraud at examinations, and the question is raised whether resumption of the old system of special watchman or "proctors" may not prove wise.

The number of students in attendance has risen continuously of late until, in the last academic year, there were registered, in all classes and courses, 2980. The largest body was in the College of Arts and Sciences, 755, and the next largest in Sibley College, 661. The gain for the year 1899–1900 was, total, 214, in Arts and Sciences 75, in Sibley College 90. It may be remarked that, in the latter institution, the present year sees, already, a gain of *over one hundred* above the whole registration of the year 1900–1901. This increase, as the President states, makes desirable an

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addition of not less than $1,000,000 to the endowments of the University in invested funds. The rapid summary of the work of the several colleges includes, as perhaps its most striking feature, the account of the College of Agriculture and its promotion of extension-work in the state. It teaches 25,000 farmers through its reading classes, about 5,000 farmers' wives, 11,500 teachers of nature-study, and 21,000 children; issuing 2,770,000 pages, *per annum*, of printed matter for their use, and also printing bulletins of the Experiment Station, to the number of 4,240,000 pages. Yet the State of New York has not done as much for the University, in the aggregate of its appropriations for constructions on the Campus, as is measured by two years' expenditure by the University on state scholars.

Referring to Sibley College, the report reads as follows:

"In this College, 660 undergraduates were enrolled during the year. The number who graduated in June was 110. Owing to the recent elevation of the entrance requirements, the graduate of to-day completes in his four years' course what would formerly have been the work of five years. The members of the graduating class immediately received appointments to positions. This fact reveals a great change in the attitude of business men towards technical and scientific training. Formerly they did not care to take graduates into their employment; now the industrial interests of the country are gradually drifting into the hands of young men who have been educated in technical colleges. Cornell University may claim that through the work of Sibley College it has contributed to this revolution; certainly its graduates in mechanical and electrical engineering get their full share of responsible positions in the great world of industry.

"It is the honor of Cornell University to have been a leader in the introduction and fruition of technical education in the United States. England and Europe are now following this example. The new University of Birmingham, on the advice of Mr. Carnegie, sent a committee of investigation to this country, and this committee recommended the adoption by Birmingham of the system of engineering education they found at Cornell—a system they declared to be 'admirably planned and carried out.' Similar commendations have been received from eminent visiting scientists from Germany. But while the present organization and facilities of Sibley College excite general admiration, the Director and the Faculty know that, through the penalty of success, they have now become inadequate to the demand they have created. In the

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great departments of experimental engineering and electrical engineering—subjects big with the industrial developments of the future—not only does the work of instruction need reinforcement and enlargement, but provision should be made for their establishment on a large scale of systematic investigation and research with a view to the discovery and utilization of new laws of nature for the advancement of the industrial interests of the Nation and the good of mankind.

"While the Faculty has raised the scientific requirements of the Course in Mechanical Engineering, no reduction has been made in the shopwork heretofore prescribed. A certain skill in the mechanic arts is deemed essential for the mechanical engineer, not only because he thus learns to 'do things,' but also because the practical applications made in the machine-shop give definiteness to his scientific theories and secure accuracy of attainment. In a sound technical course, theory must thus be interfused with practice. This has always been a leading characteristic of Cornell, and it has given a definite mark to its students. The large increase of students in Sibley College is making severe demands upon the shops, and further extension will soon be necessary.

"The gift of Mr. Hiram W. Sibley for the erection of a new building connecting the eastern and western fronts of Sibley College, with a dome surmounting the whole, was made since the writing of the last report. The new structure thus happily provided for will cost from $70,000 to $80,000. It is not the first large benefaction to Cornell University from Mr. Hiram W. Sibley, who nobly emulates the generosity of his father, the late Hiram Sibley, to whose munificence the existence of Sibley College is due.

"The Director's report presents with considerable detail the operations and needs of the Sibley College of Mechanical Engineering. In referring to it for further information, the President desires to quote, appropriate, and heartily endorse the following pregnant sentence: 'We have now secured such a standing and such recognition as permits, given the needed capital and the privilege of using it effectively, making Cornell University an important centre, if not *the* centre, of this kind of professional work for the State and probably for the country.'"

The appendix to the report contains the reports to the President, of the Deans and Directors of the several colleges and of other officers of the University. These need not be abstracted; especially as we have given an abstract of the more detailed report of the Director of Sibley College in an earlier issue. The text, here ab-

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stracted, of the President's report, requires little comment ; but a word may enforce the very important suggestions of its author.

The changes in the list of officers of the University have, as always, affected Sibley College most seriously. The inability of the University to offer first-class men first-class salaries, as mentioned by the President, much less to pension them, annually causes the loss to the college of able men who accept better business or other opportunities, though much preferring to remain at Cornell, and who would choose, if permitted, the life of the scholar rather than that of the money-maker, the home with Alma Mater rather than among strangers. The college, fortunately, always finds able men ; but their value is always greater to Cornell than it can be to another institution and that value increases constantly with experience ; they should be retained by suitable rank and pay, while those who now make a continual sacrifice by remaining should be still more considered.

Regarding the point made respecting the moral standards of the community : it should be said that, in Sibley College certainly, the feeling, on the part of every student who has given thought to the matter, is that, it being assumed by the authorities, as always has been the case, that "every student is expected to be a gentleman and that every gentleman in the college is expected to be a student", it remains for the student-body itself to cultivate and maintain that spirit of self-respect, that fine sense of honor and that jealousy of the honor and reputation of our Alma Mater which is essentially a characteristic of every gentleman and scholar. Such a spirit exists at Cornell, as it does at other institutions having reputation for scholarship and learning and an atmosphere of courtesy and consideration. That students are promptly amenable to any appeal to this spirit has been many times shown at Cornell by their instant acquiescence in suggested improvements in class and college methods involving, for example, class-rushes, athletics and student-gatherings generally. It is always but a small minority who fail to appreciate and respond to any such appeal and the influence of the best men in college may always be relied upon to become effective when the occasion is seen to demand its exertion for the good of the University. When the many gentlemen and scholars assert themselves, the small minority of the ill-disposed, who are always responsible for any injury to the standing of the University, retire.

The growth of the University is particularly gratifying, and more than proportionately embarrassing, in Sibley College ; where there are over a hundred more students this year than last, and

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where the pressure will be even more serious when the new building is completed than before it was begun. It is especially encouraging, though otherwise trying, to observe that this field into which young men are flocking in such numbers is that in which the country most needs them, at the moment, and the demand is becoming more earnest and imperative, all the time, in spite of this increasing supply. Not only does the opportunity offer for the useful employment of all the funds that Sibley College may receive from its always generous old friends and supporters, but it is certain that there will be opportunity here for all the capital that any number of similarly public-spirited investors in this field can supply. Many millions may be profitably used in the development of this work in our country and there is no better place than at Cornell University, and in the Sibley College organization, to make such investment in highest degree profitable to the youth of the country and to the nation. Should the State of New York ever arise to that altitude which every statesman desires to see her attain, and which every good citizen desires for her, making it an obviously primary task to educate her citizens for the future of their lives, if possible more effectively than even Germany has been doing this work for many decades, the first result will be the full compensation of the Land Grant College of the State for its sacrifices and for its earlier good works, and then provision for its proper, its liberal, support thereafter. Then these criticisms and complaints and these embarrassments will cease and a work will be here performed which will astonish and delight every intelligent observer and give cause for patriotic pride to all citizens. To-day the State pays into the treasury of Cornell University an insignificant annual contribution which it, however, receives as a gift, as its share of the generous gifts of the General Government to the States, made about forty years ago. It has added little since from its own treasury, and its noblest contribution to this work of the United States government, the Veterinary College, cost the State less than is paid out of the University funds every year in the education of the six hundred "state scholars" from whom not a dollar is received for tuition. The fact is alike creditable to the University, and fortunate for the country, which is thus given free education of some of its brightest minds—but it is exceedingly discreditable to the State and very mortifying to every thoughtful citizen, conversant with the wealth of the "Empire State" and the straits to which its great University is reduced by its success as an institution of learning.

R. H. THURSTON.

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TRAIN RESISTANCE FORMULAS.

JOHN G. CRAWFORD.

It is not the purpose of this article to discuss the various component parts of train resistance, but to take up the subject as a whole, with special reference to the resistance of that portion of the train behind the tender. In substance, this article is an abstract of the train resistance chapter of the thesis of the writer and Geo. W. Ristine, Jr., presented to Cornell University, for the degree of Mechanical Engineer in June, 1901. The writers of this thesis were assistants on the Chicago, Burlington & Quincy R. R. tests referred to in the latter part of the article, and a number of train resistance formulas were collected for comparison with the formula derived by the writer.

The earlier formulas for train resistance and a few of those derived in recent years were deduced from experiments on slow speed trains, hence it is no wonder that they do not hold at speeds three or four times that of their experimental limits. Many of these formulas have been used and advocated long after their period of usefulness has passed.

The relation of resistance to speed has been expressed in various forms, as will be seen on examining the formulas here collected. Any general formula with the necessary variables and constants to fit any case would be very complex. It is probable that with no wind, the resistance of a train running on a straight and level track without change of speed might be expressed by the formula,

$$R = a + b\,V + c\,V^n;$$

where a, b, c and n are constants; V = the velocity, and R = the resistance of the train at the speed V. With chosen constants this formula would be applicable only to a certain class of trains.

In the first place it must be decided whether the formula is to include the resistance of engine, tender and cars, or of the cars alone. The loading of the cars must be taken into account, for the resistance per ton of loaded cars would be less than the resistance per ton for the same cars empty. This is due to the decrease in the coefficient of journal friction with increase of load, and also to the fact that the atmospheric resistance is the same whether the cars are empty or loaded. Another consideration, which, like the previous one, involves the relation of weight to volume, is that of the comparative weights of the cars.

A number of varying formulas for train resistance are here

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given, and it is interesting to note that the general tendency from year to year has been to give lower values for train resistance, especially at the high speeds. Fig. 1 is a diagram showing graphically the comparison between various formulas.

In comparing any two formulas the conditions of the experiments on which they are based should be considered.

The following notation is used :

R = resistance in lbs. per ton.
V = velocity in miles per hour.
L = length of train in feet, exclusive of engine and tender.
T = weight of train in tons, exclusive of engine and tender.
E = weight of engine and tender.
A = area of frontage in square feet.

Unless otherwise stated, tons are 2,000 lbs.

Where formulas are given in metric units the notation is as follows :

V = velocity in kilometers per hour ;
R = resistance in kilograms per tonne.

Formulas given in long tons and metric units are followed by their equivalents in short tons.

D. K. Clark gives in his book "Railway Machinery" the following formulas for long tons :

Engine, tender and train.

$$R = \frac{V^2}{171} + 8 \text{ (Long tons).}$$

$$R = \frac{V^2}{191.5} + 7.2 \text{ (Short tons).}$$

Train alone.

$$R = \frac{V^2}{240} + 6 \text{ (Long tons).}$$

$$R = \frac{V^2}{269} + 5.4 \text{ (Short tons).}$$

These were published in 1854, and were based on the experiments of Mr. Gooch, which covered several years. The experiments were made on the wide gage (7-ft.) roads, at low speeds, and general conditions were not favorable to easy running.

In Rankine's "Civil Engineering" is found this formula, given by Mr. Gooch for train, exclusive of engine and tender,

$$R = 6 + \frac{V - 10}{3.3} \text{ (Long tons).}$$

$$R = 5.4 + \frac{V - 10}{3.7} \text{ (Short tons).}$$

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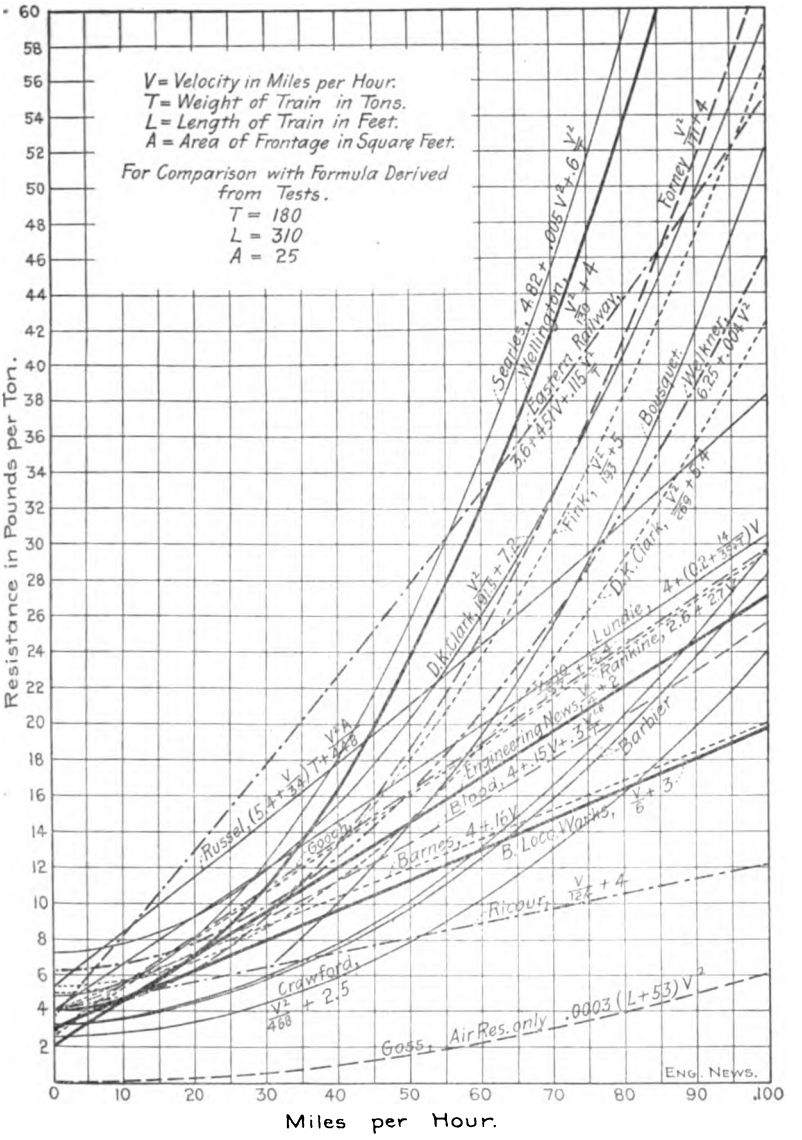

FIG. 1. COMPARATIVE DIAGRAM OF TRAIN RESISTANCE CURVES REPRESENTING VARIOUS FORMULAS.

Of the above curves the following are mentioned by Mr. John B. Blood in the *Street Railway Journal* of May, 1899: Searles' formula of $4.82 + .005\ V^2 + .6\ \frac{V^2}{T}$ is the formula given in this article, reduced by Mr.

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The formulas of Rankine, as given in his "Useful Rules and Tables" are similar to D. K. Clark's, and according to conditions take any value between the following limits,

$$R = 2.7 + \frac{V^2}{540} \text{ (Long tons).}$$

$$R = 2.4 + \frac{V^2}{605} \text{ (Short tons).}$$

and

$$R = 8 + \frac{V^2}{180} \text{ (Long tons).}$$

$$R = 7.1 + \frac{V^2}{202} \text{ (Short tons).}$$

A reference to Mr. Scott Russell's formula is found in Van Nostrand's "Engineering Magazine" of 1877, page 490. This formula is for the train, exclusive of locomotive, and takes separate account of head resistance,

$$R = \left(6 + \frac{V}{3}\right) + \frac{V^2 A}{400\,T} \text{ (Long tons).}$$

$$R = \left(5.4 + \frac{V}{3.4}\right) + \frac{V^2 A}{448\,T} \text{ (Short tons).}$$

Wellington, in his "Economic Theory of Railway Location," gives Searle's formula for resistance of entire train,

$$R = 4.82 + 0.005357\ V^2 + \frac{.0004783\ V^2 E^2}{T + E}.$$

Wellington, as a result of his tests made on the Lake Shore in 1878, gives for loaded freight cars,

$$R = \frac{V^2}{130} + 4.$$

These tests were made at speeds under 30 miles per hour, and the "drop test" system was used.

Blood to include only resistance of cars. The Eastern Railway formula is for speeds ranging from 43 to 50 miles per hour. Welkner's curve was derived at low speeds. Rankine's formula, $R = 2.6 + .27\ V$, and Blood's, are given in the above-mentioned article.

Upper Barbier curve is drawn as published in the *Railroad Gazette*. The lower curve was reduced from the original formula by Ristine and Crawford.

The curve marked Bousquet was drawn from a table of resistance published a few years ago.

The curve marked Barnes, $R = 4 + .16\ V$, is one atrributed to him and is not drawn from the accompanying table.

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Mr. John B. Blood, in the *Street Railway Journal* of May, 1899, gives this formula as Wellington's,

$$\text{Total Res.} = 4(T+E) + 0.28\,V^2 + 0.03\,V^2 C + 0.005\,V^2(T+E);$$ where C = number of cars.

Beginning at the left, the terms represent, journal friction, head resistance, side atmospheric resistance, and resistance due to concussion and oscillation.

Boulvin, in "Cours de Mécanique Appliqué aux Machines," gives a formula derived by Fink, a Prussian engineer, which applies to train alone,

$$R = 2.5 + 0.001\,V^2 \text{ (Metric units).}$$

$$R = 5 + \frac{V^2}{193} \text{ (Short tons).}$$

Ricour, in 1885, gave for the resistance of the train alone,

$$R = \frac{V}{40} + 2 \text{ (Metric units).}$$

$$R = \frac{V}{12.4} + 4 \text{ (Short tons).}$$

Ricour's formula is given in Wellington's "Economic Theory of Railway Location."

Forney, in an article published in *Scribner's Magazine* of March, 1892, gives a curve whose formula is,

$$R = \frac{V^2}{171} + 4.$$

As it is so near Clark's formula, it probably includes resistance of engine and tender.

D. L. Barnes, in the *Engineering Magazine*, in 1894, gave a curve for train resistance at speeds from 50 to 100 miles per hour. It is said to have been derived from the results of tests on the C. B. & Q. R. R., and the Pennsylvania R. R. The experimental range of this curve is probably from 50 to 70 miles per hour. The following table gives the various resistances,

V	50	60	70	80	90	100
R	12.0	12.4	13.5	15.0	17.0	20.0

Barbier, in *Le Génie Civil* of April 8, 1898, gives the following formula for cars alone,

$$R = 1.6 + 0.456\,V\left(\frac{V+10}{1000}\right) \text{ (Metric units).}$$

$$R = 3.2 + 2.36\,V\left(\frac{V+6.21}{1000}\right) \text{ (Short tons).}$$

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These experiments covered a period of four years (1891–1895), and were made in all seasons of the year. The speed range was from 39 to 69 miles per hour. The weight of trains, exclusive of engine and tender, ranged from 120 to 210 tons, and the average weight was 160 tons.

Prof. W. F. M. Goss, in the *Railroad Gazette* of May 20 1898, gives the results of tests on model cars, $\frac{1}{32}$ actual size, to determine the effect of air resistance. The following formula gives the resistance offered by still air to that portion of a train which follows a locomotive tender,

$$\text{Total Res.} = 0.0003\,(L + 53)\,V^2.$$

The *Engineering News'* formula is,

$$R = \frac{V}{4} + 2.$$

This includes all resistance except the internal frictional resistance of the locomotive. The curve represented by this equation at speeds of from 60 to 70 miles per hour, was determined by indicator cards taken on the engine hauling the "Empire State Express." The curve at low speed was determined by taking the average results of various tests.

The formula used by the Baldwin Locomotive Works is,

$$R = 3 + \frac{V}{6}.$$

It was derived from indicator cards taken on a Vauclain four-cylinder compound, and hence is for engine, tender and train. The data were obtained on three runs on the Atlantic City Railroad from Camden to Atlantic City, a distance of 56 miles. The trains were made up as follows:

(1) A six-coach train, two of which were Pullman's.

(2) An eight-coach train, three of which were Pullman's.

(3) A twelve coach train, four of which were Pullman's.

Mr. John Lundie, from experiments on the South Side Elevated Railway, of Chicago, deduced the following formula:

$$R = 4 + V\left(0.2 + \frac{14}{35 + T}\right)$$

See *Street Railway Journal*, March, 1899.

In these experiments, the "drop test" system was used. The train ranged in weight from 21 to 82 tons, and the upper limit of speed was only 26 miles per hour. The formula includes resist-

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ance of motors, and is probably useful only in electric railway work.

In July, 1900, some tests were made on the Chicago, Burlington & Quincy R. R., under the direction of Mr. Max H. Wickhorst, Engineer of Tests, to determine the cost of running trains at high speed. The tests consisted of five runs from Chicago, Ill., to Burlington, Ia., a distance of 206 miles. Three runs were made on fast mail train No. 15, its schedule running speed being 55 miles per hour; and two runs were made on a special train of the same make-up, but run at half the speed. The fast mail train

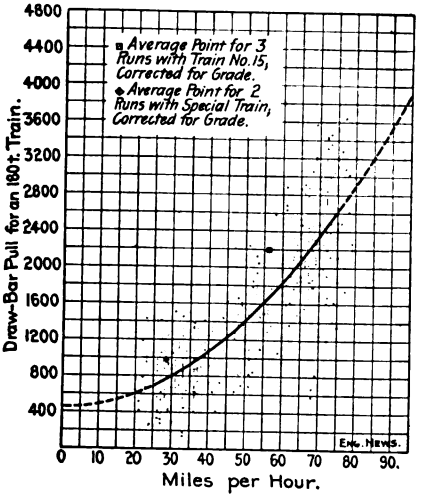

FIG. 2. TRAIN RESISTANCE RECORDS AND CURVES.

Each point represents ½ mile; corrected for grade and acceleration.
Train No. 15 weighed 180 tons.
Special train weighed 160 tons.
Points from special runs reduced to 180-ton equivalents.

consisted of dynamometer car, two baggage and two mail cars; its total average weight behind the tender was 180 tons. The special train consisted of similar cars, carried no lading, and averaged 160 tons.

The dynamometer paper furnished a continuous record of speed and drawbar pull. This paper feeds one ft. per mile, and on that account it was convenient for the purposes of planimetering to divide the paper into half-mile sections, and then find the mean drawbar pull for each half-mile section. An electrically-operated

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time pen recorded each five seconds, and from this record the speed in miles per hour was computed for each half-mile.

In order to reduce the probability of error to a minimum, for finding the speed-drawbar pull curve, only those portions of the dynamometer paper were selected, which showed that there had been little change of the speed of the train in the run of the half-mile, and where the grade correction would also be small. No correction was made for the curvature, but all the observations on heavy curves were omitted. In obtaining some of the extreme speeds it was necessary to make considerable grade correction. Of the 2,060 values of speed and drawbar pull, only 333 were used in finding a relation between speed and drawbar pull.

Since the dynamometer paper feeds 1 ft to the mile, the number of spaces of 1·60-in. which can be interposed between the marks representing five seconds gives the speed in miles per hour. Thus the speed of the train, on entering and leaving a half-mile block was found. The difference in height of the track between the beginning and end of the half-mile block was found from the profile of grades. Hence, knowing the change of velocity of the train and its rise or fall in the half-mile, acceleration and grade corrections are found. Each of the 333 points, representing 166.5 miles, was corrected and plotted, as shown in Fig. 2. The points surrounded by squares represent the average drawbar pull and speed from Chicago to Burlington. Burlington is 80 ft. lower than Chicago, and this grade correction was made, but these average points include resistance of curves and lost energy due to use of brakes.

The points are seen to be scattered on either side of the line drawn to represent their mean. This is caused by errors in the acceleration correction, but as consecutive sections of the dynamometer were selected, a positive error in one block is a negative one in the next, and hence they tend to balance. The curve given in Fig. 3 is that of Fig. 2, reduced to lbs. per ton.

The points in each half-mile column were averaged, and note made of the number of points represented in the average; then the weighted mean was drawn, and the equation of the curve was found to be,

$$R = \frac{V^2}{468} + 2.5.$$

This equation was derived from experimental data representing 166.5 miles of running. As the speed range was from 25 to 75

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miles per hour it cannot be expected to hold for low speeds; also it cannot be expected to hold for all classes of trains. As will be seen by reference to Fig. 1, it compares favorably with Barbier's

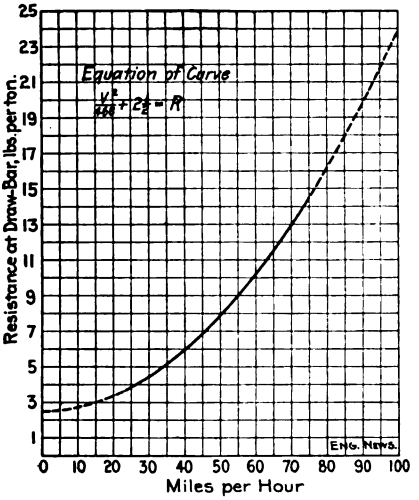

FIG. 3. TRAIN RESISTANCE CURVE DERIVED BY JOHN G. CRAWFORD. Checked by Geo. W. Ristine, Jr. Certified by Prof. R. C. Carpenter.

experiments, which were made in all seasons of the year, while those on the C., B. & Q. R. R. were made when the mean temperature of the atmosphere was 70° and the wind was very light.

NOTE.—We are indebted to *Engineering News*, by whom this article was first published, for the three cuts shown.

THE CRUSHING STRENGTH OF COAL.

PROF R. C. CARPENTER.

Coal is not often used for any purposes except that of fuel, and the crushing strength is ordinarily of little or no importance. In the process of coal mining, however, columns of coal are left standing to hold up the roof of rock over the coal seam and keep it from falling after the coal has been removed. There is a constant temptation to reduce these columns of coal so much that they do not form a safe support for the roof, and several serious accidents have happened in the coal regions from such causes. It is evidently of considerable importance in coal mining work

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that the size of the column be sufficient to sustain the load of rock above it, and on the other hand for financial reasons it should be made as small as is consistent with safe mining. For these reasons an investigation of the strength of coal is to be considered of considerable importance in connection with mining operations.

The results of tests which were made in the Mechanical Laboratory of Sibley College to determine the crushing strength of various samples of coal are given in tabular form on the following pages. These tests were made at the request of Mr. William Griffith, Chairman of a Committee appointed by the Scranton Engineers' Club to make this investigation. This committee supplied us with all specimens and all information regarding the location to which the specimen belonged and its general characteristics. The specimens as received were cut to the uniform sizes, 2 x 2 x 1, 2 x 2 x 2 and 2 x 2 x 4 inches. They were tested in compression in the form of columns respectively, 1", 2" and 4" in height, with the uniform cross section of 4 square inches. In order to get the force distributed uniformly over the entire surface of the specimen, a thin layer of plaster of Paris was placed between the end of the column and the bed of the testing machine. Pressure of a few pounds per square inch was brought on the column and the whole was then allowed to stand from 15 to 20 minutes for the plaster to thoroughly set before applying any heavier load. An extended experience in the testing of stone, brick and similar substances in compression has proved that the method of bedding the specimens in a thin layer of plaster of Paris secures a perfect distribution of the force and more reliable results than the use of any other material which has been recommended to us. Previous to putting the specimens in the machine, they were chalked on the four sides so that the first cracks could be more readily seen. Pressure was then slowly applied and when the first visible checks showed in the chalked surface the reading of the scale beam was taken, which is designated as load 1 on the sheet attached. Pressure was then applied until the column was crushed, the maximum load supported being given as load 2 on the log sheet. The following log sheet gives in tabular form the vein, from which the coal was obtained, size of specimen, how tested, character of coal, strength at first check and maximum strength, location of colliery, depth below surface, pitch of seam and all other information furnished by the committee. In all cases the coal was taken from the face, except where marked "P", in which it was taken from the pillar.

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DATA OF TEST OF MECHANICAL STRENGTH OF COAL.

Vein.	Size of specimen.	Character of coal.	Load 1 1st crack.	Load 2 maximum	Location of colliery.	Location from which taken.	Pitch of seam—Degs.	Depth below surface—Ft.
AVONDALE.—D. L. & W. COAL.								
Red Ash	2 x 2 x 1	Bright	8,700	13,760	Plymouth	Half way	15	800
"	2 x 2 x 2	"	8,400	9,350		between	15	800
"	2 x 2 x 4	"	7,300	8,800*a*	Township.	Basin and outcrop.	15	800
Ross	2 x 2 x 1	Bright	7,800	19,420	Plymouth	Half way	15	700
"	2 x 2 x 2	"	6,600	10,080		between	15	700
"	2 x 2 x 4	"	5,700	6,000*b*	Township.	Basin and outcrop.	15	700
ALDEN COAL COMPANY.								
Red Ash	2 x 2 x 1	Glassy	14,200	26,310	Alden,	300 feet to outcrop	30	200
"	2 x 2 x 2		8,700	10,950	Luzerne Co.,	" " "	30	200
"	2 x 2 x 4	Bright	7,900	10,460	Pa.	" " "	30	200
Bennett	2 x 2 x 1	Checker	16,600	30,090*b*	Alden,	400 feet to basin	18	600
"	2 x 2 x 2		11,600	17,770	Luzerne Co.,	" " "	18	600
"	2 x 2 x 4	Bright	9,000	11,750	Pa.	" " "	18	600
Mills	2 x 2 x 1	Glassy	12,800	27,230	Alden,	100 feet to basin	20	450
"	2 x 2 x 2		7,000	12,870	Luzerne Co.,	" " "	20	450
"	2 x 2 x 4	Bright	9,000	10,440	Pa.	" " "	20	450
LANGLIFFE COAL COMPANY.								
Dunmore No. 3	2 x 2 x 1	Dull	4,800	23,700	Avoca	Near saddle	3	180
"	2 x 2 x 2	"	7,000	9,700	Luzerne Co.,	" "	3	180
"	2 x 2 x 4	"	7,000	9,400	Pa.	" "	3	180
GREENWOOD COAL COMPANY.								
Dunmore No. 2	2 x 2 x 1	Dull	8,800	26,500	Greenwood,	Near basin		140
"	2 x 2 x 2	"	6,500	15,800	Lacka. Co.,	" "		140
"	2 x 2 x 4	"	9,100	9,800	Pa.	" "		140

a. Broke out at one side. *b*. Went to pieces.

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VEIN.	Size of Specimen.	Character of Coal.	Load 1 1st crack.	Load 2 Maximum	Location of Colliery.	Location from which taken.	Pitch of seam—Degs.	Depth below surface—Ft.
CONNELL COAL COMPANY.								
Lower Split	2 x 2 x 1	Slightly	9,100	20,300	Old Forge,	Normal.	2	165
Red Ash	2 x 2 x 2		6,500	7,900	Lacka. Co.,	"	2	165
"	2 x 2 x 4	Checker	8,400	10,600	Pa.	"	2	165
Top Split	2 x 2 x 1	Bright	6,500	19,100	Old Forge,	Normal.	Flat.	241
Red Ash	2 x 2 x 2	"	5,200	6,600	Lacka. Co.,	"	"	241
"	2 x 2 x 4	"	7,100	8,400	Pa.	"	"	241
Middle Split	2 x 2 x 1	Bright	10,700	17,700	Old Forge,	Normal.	Flat.	260
Red Ash	2 x 2 x 2	"	8,700	8,700	Lacka. Co.,	"	"	260
"	2 x 2 x 4	"	9,400	9,400	Pa.	"	"	260
PARRISH COAL COMPANY.								
Old Bennett	2 x 2 x 1	Dull	7,200	28,300	Two miles	Half way	8	527
"	2 x 2 x 2	"	10,200	24,000	below	between	8	527
"	2 x 2 x 4	"	6,200	10,600	Wilkes-Barre.	Basin and outcrop.	8	527
Hillman	2 x 2 x 1	Bright	9,500	19,170	Two miles	Half way	8	467
"	2 x 2 x 2	"	5,800	10,810	below	between	8	467
"	2 x 2 x 4	"	4,800	6,710	Wilkes-Barre.	Basin and outcrop.	8	467
Kidney	2 x 2 x 1	Bright	11,300	21,600	Two miles	Half way	8	370
"	2 x 2 x 2	"	8,400	19,200	below	between	8	370
"	2 x 2 x 4	"	7,300	9,290	Wilkes-Barre.	Basin and outcrop.	8	370
Five Foot	2 x 2 x 1	Dull	15,000	26,930	Two miles	Half way	8	640
"	2 x 2 x 2	"	7,400	9,850	below	between	8	640
"	2 x 2 x 4	"	6,000	11,120	Wilkes-Barre.	Basin and outcrop.	8	640
Baltimore	2 x 2 x 1	Bright	5,200	14,560	Two miles	Half way	8	700
"	2 x 2 x 2	"	7,600	16,350	below	between	8	700
"	2 x 2 x 4	"	12,300	18,320	Wilkes-Barre.	Basin and outcrop.	8	700

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Vein.	Size of specimen.	Character of coal.	Load 1 1st crack.	Load 2 maximum	Location of colliery.	Location from which taken.	Pitch of seam—Degs.	Depth below surface—Ft.
AVONDALE.—D. L. & W. COAL.								
Ross	2 x 2 x 4	Bright	4,500	8,000	Plymouth	Half way between	15	700
"	2 x 2 x 2	"	3,000	6,200			15	700
"	2 x 2 x 1	"	5,200	10,700	Township.	basin and outcrop.	15	700
Red Ash	2 x 2 x 4	Bright	6,800	6,800	Plymouth	Half way between	15	800
"	2 x 2 x 2	"	4,600	9,000			15	800
"	2 x 2 x 1	"	6,200	25,000	Township.	basin and outcrop.	15	800
LYKENS VALLEY COAL COMPANY.								
Whites	2 x 2 x 4	Dull	3,100	3,600	Lykens,	Midway between	18	1,300
"	2 x 2 x 2	"	3,600	6,100	Dauphin Co.,		18	1,300
"	2 x 2 x 1	"	2,000	12,700	Pa.	crop and basin.	18	1,300
Lykens Valley	2 x 2 x 4	Dull	3,000	8,000	Lykens,	Midway between	30	1,200
"	2 x 2 x 2	"	4,100	7,600	Dauphin Co.,		30	1,200
"	2 x 2 x 1	"	3,000	8,300	Pa.	crop and basin.	30	1,200
Little Lykens Valley	2 x 2 x 4	Dull	3,400	4,500	Lykens,	Midway between	20	1,300
"	2 x 2 x 2	"	2,400	3,000	Dauphin Co.,	crop and basin	20	1,300
"	2 x 2 x 1	"	4,000	15,000	Pa.	near saddle.	20	1,300
SUMMIT BRANCH COAL COMPANY.								
No. 9½ vein White Ash	2 x 2 x 4	Bright	3,700	7,000	Williamstown,	Midway between	70	820
"	2 x 2 x 2	"	4,800	6,100	Dauphin Co.,		70	820
"	2 x 2 x 1	"	6,000	14,000	Pa.	crop and basin.	70	820
No. 9 vein White Ash	2 x 2 x 4	Bright	3,800	3,800	Williamstown,	P ⅔ from basin *	70	820
"	2 x 2 x 2	"	4,800	11,200	Dauphin Co.,		70	820
"	2 x 2 x 1	"	2,800	15,900	Pa.	to crop.	70	820
No. 7 vein White Ash	2 x 2 x 4	Bright	6,900	8,200	Williamstown,	P 800 feet from †	60	700
"	2 x 2 x 2	"	2,600	4,900	Dauphin Co.,		60	700
"	2 x 2 x 1	"	5,300	10,300	Pa.	crop.	60	700

* Pillar has been standing nine years. † Pillar has been standing one year.

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Vein.	Size of Specimen.	Character of Coal.	Load 1 1st crack.	Load 2 Maximum	Location of Colliery.	Location from which taken.	Pitch of seam—Degs.	Depth below surface—Ft.
				DELAWARE AND HUDSON COAL CO.				
Carbondale top vein	2 x 2 x 1	Dull	9,700	22,200	Coal Brook mines, Carbondale, Pa.	Near basin	Flat	100
"	2 x 2 x 2	"	7,400	18,800		" "	"	100
"	2 x 2 x 4	"	8,000	8,500		" "	"	100
Top coal	2 x 2 x 1	Bright	11,600	21,600	Vandling, Lacka. Co., Pa.	Near basin	3	200
"	2 x 2 x 2	"	8,100	17,400		" "	3	200
"	2 x 2 x 4	"	8,000	11,900		" "	3	200
Carbondale 3d vein	2 x 2 x 1	Dull	4,300	17,700	Coal Brook mines, Carbondale, Pa.	Near basin	5	105
"	2 x 2 x 2	"	3,700	5,700		" "	5	105
"	2 x 2 x 4	"	5,800	7,900		" "	5	105
Carbondale bottom	2 x 2 x 1	Bright	9,000	16,500	Coal Brook mines, Carbondale, Pa.	Near saddle	12	120
" coal	2 x 2 x 2	"	2,300	2,800		" "	12	120
"	2 x 2 x 4	"	5,600	7,500		" "	12	120
Mills	2 x 2 x 1	Bright	7,000	26,500	Coal Brook mines, Carbondale, Pa.		5	75
"	2 x 2 x 2	"	5,400	12,200			5	75
"	2 x 2 x 4	"	5,000	8,300			5	75
Bottom	2 x 2 x 1	Dull	4,300	33,200	Vandling, Lacka. Co., Pa.	Near basin	2	214
"	2 x 2 x 2	"	9,500	19,600		" "	2	214
"	2 x 2 x 4	"	5,800	7,600		" "	2	214
Clifford	2 x 2 x 1	Dull	8,800	29,700	Vandling, Lacka. Co., Pa.	Near basin	2.5	230
"	2 x 2 x 2	"	6,400	15,100		" "	2.5	230
"	2 x 2 x 4	"	7,900	12,500		" "	2.5	230
Rock	2 x 2 x 1	Dull	6,100	26,300	Olyphant, Pa.	Near basin	1	310
"	2 x 2 x 2	"	5,800	14,100		" "	1	310
14 foot	2 x 2 x 1	Glassy	9,500	25,200	Olyphant, Pa.	2,000 ft. from outcrop	5	300
No. 2	2 x 2 x 2	Checker	6,800	15,600		Near outcrop	1	90
No. 2	2 x 2 x 1	Checker	8,600	25,000	Olyphant, Pa.	Near outcrop	1	90
14 foot	2 x 2 x 2	Glassy	7,500	15,400		2,000 ft. from outcrop	5	300
Diamond	2 x 2 x 1	Bright	5,800	17,200	Olyphant, Pa.	Regular	1	200
"	2 x 2 x 4	"	11,700	14,300		"	1	200

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VEIN.	Size of Specimen.	Character of Coal.	Load 1 1st crack.	Load 2 Maximum	Location of Colliery.	Location from which taken.	Pitch of seam—Degs.	Depth below surface—Ft.
DELAWARE AND HUDSON COMPANY.								
Grassy Island or 14 ft.	2 x 2 x 1	Bright	11,550	24,770	Jermyn,	Near basin.	4	95
"	2 x 2 x 2	"	9,380	14,660			4	95
"	2 x 2 x 4	"	11,500	14,220	Penn.		4	95
Archibald or Clark	2 x 2 x 1	Checker	14,230	23,500	Jermyn,	1000 feet from basin.	3	84
"	2 x 2 x 2	"	13,350	15,800		P *	3	84
"	2 x 2 x 4	"	5,600	6,350	Penn.		3	84
No. 4	2 x 2 x 1	Checker	10,570	14,570	Scranton,	Near basin.	3	471
"	2 x 2 x 2	"	7,580	12,360	Dickson		3	471
"	2 x 2 x 4	"	8,000	8,000	Colliery.		3	471
4 ft.	2 x 2 x 1	Checker	12,500	22,400	Scranton,	Near outcrop.	2	40
"	2 x 2 x 2	"	12,200	16,400			2	40
"	2 x 2 x 4	"	8,100	10,470	Van Storch.		2	40
Diamond	2 x 2 x 1	Checker	11,580	12,584	Scranton.	Near outcrop.	2½	172
"	2 x 2 x 2	"	8,840	16,120	"		2½	172
"	2 x 2 x 4	"	6,400	9,100	"		2½	172
Rock	2 x 2 x 1	Bright	9,000	19,900	Scranton	Near basin.	½	336
"	2 x 2 x 2	"	9,220	16,200	"		½	336
"	2 x 2 x 4	"	4,600	5,580	"		½	336
No. 2	2 x 2 x 1	Dull	8,100	11,750	Scranton,	Near basin.	1½	348
"	2 x 2 x 2	"	8,200	14,300	Dickson		1½	348
"	2 x 2 x 4	"	8,200	9,560	Colliery.		1½	348
Clark	2 x 2 x 1	Glassy	12,900	31,300	Scranton,	Near saddle.	2	257
"	2 x 2 x 2	"	6,600	14,200	Dickson		2	257
"	2 x 2 x 4	"	4,920	5,760	Colliery.		2	257

* Pillar has been standing fifteen years.

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Vein.	Size of Specimen.	Character of Coal.	Load 1 1st crack.	Load 2 Maximum	Location of Colliery.	Location from which taken.	Pitch of seam—Degs.	Depth below surface—Ft.
DELAWARE AND HUDSON CO.								
Clark	2 x 2 x 1	Dull	5,600	17,540	Scranton.	Near pitch	14	158
"	2 x 2 x 2	"	9,990	21,260	Scranton.	" "	14	158
"	2 x 2 x 4	"	12,800	19,000	Scranton.	" "	14	158
4 foot	2 x 2 x 1	Dull	8,400	15,000	Scranton,	Near basin	Flat	155
"	2 x 2 x 2	"	9,300	12,700	Legitt's	" "	"	155
"	2 x 2 x 4	"	7,680	9,820	Creek.	" "	"	155
Clark	2 x 2 x 1	Bright	18,000	30,000	Scranton,	Near basin	3	419
"	2 x 2 x 2	"	9,560	19,680	Marvine	" "	3	419
"	2 x 2 x 4	"	7,000	7,000	Colliery.	" "	3	419
Clark	2 x 2 x 1	Glassy	10,780	14,660	Scranton,	Near basin	1½	590
"	2 x 2 x 2	"	13,200	15,600	Legitt's	" "	1½	590
"	2 x 2 x 4	"	2,000	2,000	Creek.	" "	1½	590
No. 4	2 x 2 x 1	Checker	13,800	22,700	Scranton,	Near basin	4	703
"	2 x 2 x 2	"	6,480	9,780	Legitt's	" "	4	703
"	2 x 2 x 4	"	8,500	10,300	Creek.	" "	4	703
14 foot	2 x 2 x 1	Glassy	14,580	18,970	Scranton.	Near basin P *	3	125
"	2 x 2 x 2	"	11,200	13,700	Dickson's	" "	3	125
"	2 x 2 x 4	"	5,000	6,295	Colliery.	" "	3	125
14 foot	2 x 2 x 1	Bright	18,400	21,700	Scranton,	Near outcrop	3	120
"	2 x 2 x 2	"	5,300	15,540	Marvine	" "	3	120
"	2 x 2 x 4	"	7,500	11,150	Colliery.	" "	3	120
Diamond	2 x 2 x 1	Checker	11,500	18,980	Scranton,	Near basin	1½	245
"	2 x 2 x 2	"	5,000	6,910	Marvine	" "	1½	245
"	2 x 2 x 4	"	6,200	7,290	Colliery.	" "	1½	245

* Pillar has been standing sixteen years.

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A FEW "CURVES OF PROGRESS."

SIDNEY GRAVES KOON.

Among the almost infinite number of curves which may be drawn, with time as one co-ordinate, nearly all of which would represent human progress in one form or another, a few may be selected as of primary interest to the engineer, as portraying progress along the particular lines to which his energies are devoted. Curves of this sort may be divided into a number of groups or classes, some depicting advances in details or processes connected with engineering enterprises, others showing the increase in the use of engineering material of various kinds. Still others show the trend of progress in lines more or less closely allied with those of more strictly engineering interest. A few such curves have been drawn, and are here presented as representative of the results which may be obtained from the study of the progress of the nation in engineering and other lines.

Plate I shows four curves representing the advances of about a century in certain details connected with steam engine practice.

The duties of steam pumping engines, from 1770 to 1890, show a continued and consistent increase, giving a smooth curve. Its convexity upwards, however, being due to a steady decrease in its slope, is indicative of a negative acceleration. The curve seems to be approaching an asymptote located somewhere in the neighborhood of 140,000,000 foot-pounds, per 100 pounds of coal. With a calorific value of 14500 B.T.U., per pound of coal, and a mechanical equivalent of 778 foot pounds per B.T.U., 100 pounds of coal has a total available energy of 1,128,000,000 foot-pounds. Our asymptotic line, therefore, would represent a total efficiency of 12.4%. One century ago, with a duty of 57,000,000, the efficiency was 5.05% ; while in 1770 it was only 0.62%.

The economy curve shows a constant and steady decrease in the coal consumption of representative engines throughout the century. No point of inflection has yet appeared, the curve continuing to drop off rapidly, and, so far, with continued acceleration. Such a point of reversed curvature must soon be reached, however, as the economy more and more nearly approaches that of the ideal engine.

The curve of steam pressures used shows the gradually, and (later) rapidly, increasing pressures representing average practice. The tendency at the end of the nineteenth century is clearly

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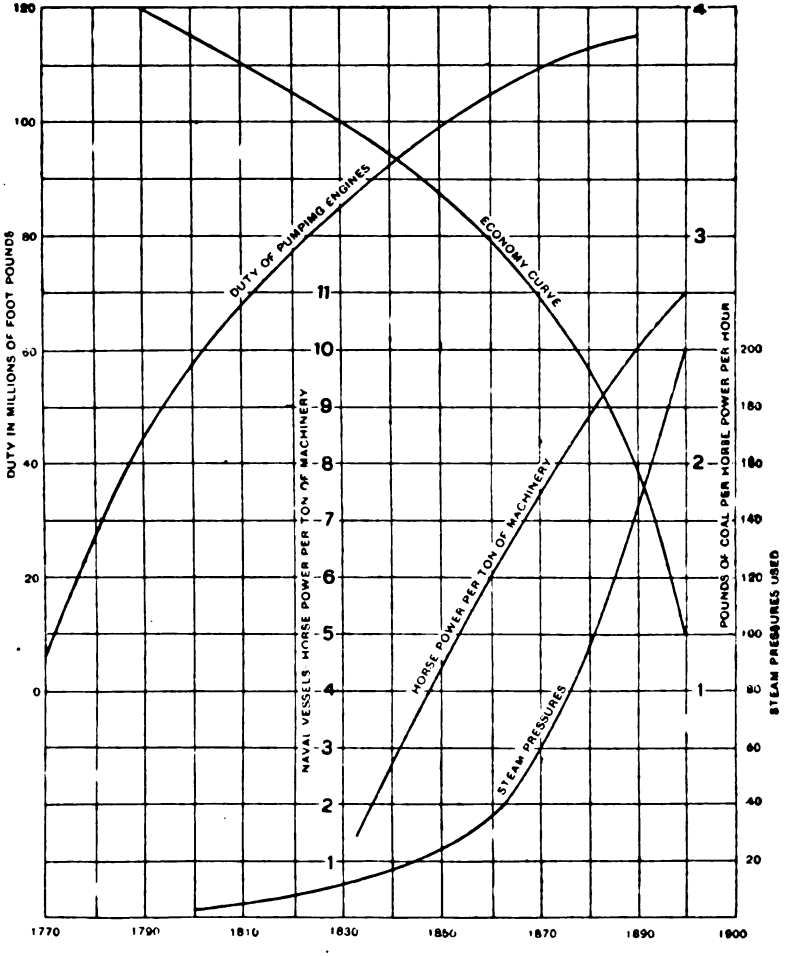

PLATE I.

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shown, by the steepness of the curve at that point, to be towards continually increasing pressures, for some time to come. Such a feature means always a higher M.E.P., with its corollary of a much smaller engine to perform any given work, or more work from a given engine. It is established mathematicially that an increase of steam pressures from 100 pounds per square inch to 1000 pounds, would increase the efficiency of the engine 50%, or in other words would reduce the required amount of heat per I.H.P. per hour to two-thirds its former value, with a corresponding reduction in the consumption of coal.

The power per unit of weight represented by practice in naval vessels, affords an interesting index of progress along constructional lines. The curve shows a continual rise, from 1.4 horse-power per ton in 1833, to about 11 to day. The convexity of the curve is here indicative of a gradually decreasing acceleration in the reduction of weights, though nothing approaching asymptotic symptoms has yet developed.

The curves in Plate II show the total power of prime movers available in the United States at various periods in our history, and the divisions and classifications under which this power falls. (Hydraulic power is not included, owing to lack of data.) It will be noticed that every one of these curves has a concavity, as viewed from above, showing accelerated growth, in every instance.

The total power is seen to have augmented enormously. The curve is now very steep, and gives no evidence of abatement. In seventy years, this has increased from 1,900,000 horse-power to 36,000,000 horse-power, a gain of 1800%, while population has increased only 493%. The horse-power per capita in 1830 was 0.15; in 1900 it was 0.47. On analysis this tremendous extension of power is found to be very largely due to the rapid increase in steam power, which is adding up at a continually increasing rate. In 1830 it is estimated that the total steam power in the United States was represented by about 200,000 horse-power; to-day it is above 20,000,000, or an increase of upwards of 10,000%. Then, there was one steam horse-power to 64 people; now, one for less than four people.

Steam power may be sub-divided into three main heads:—stationary engines, locomotives, and marine engines. Of these, the locomotive is responsible for about 60% of the total steam power, this ratio having been nearly constant during the past half-century. (Interesting curves might be drawn, showing these ratios.) Since 1880, the power of our locomotives has much more than

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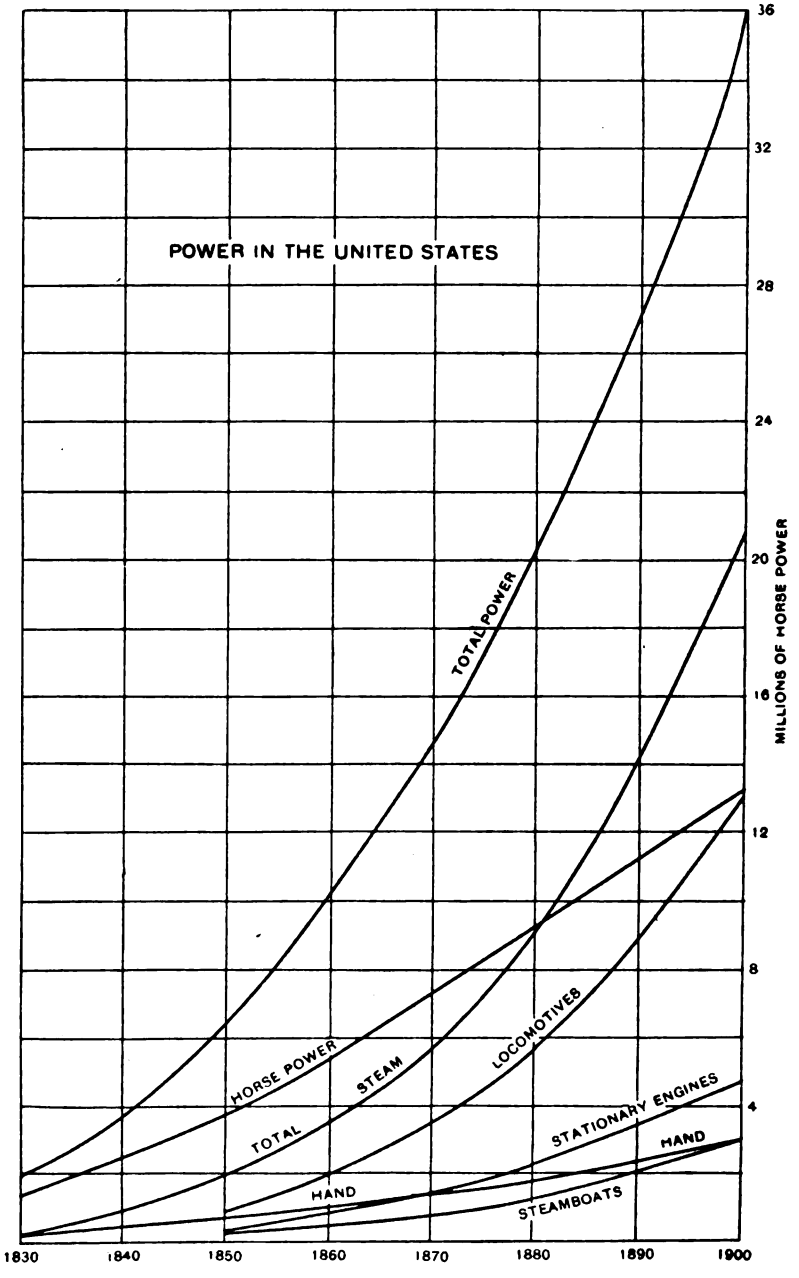

PLATE 2.

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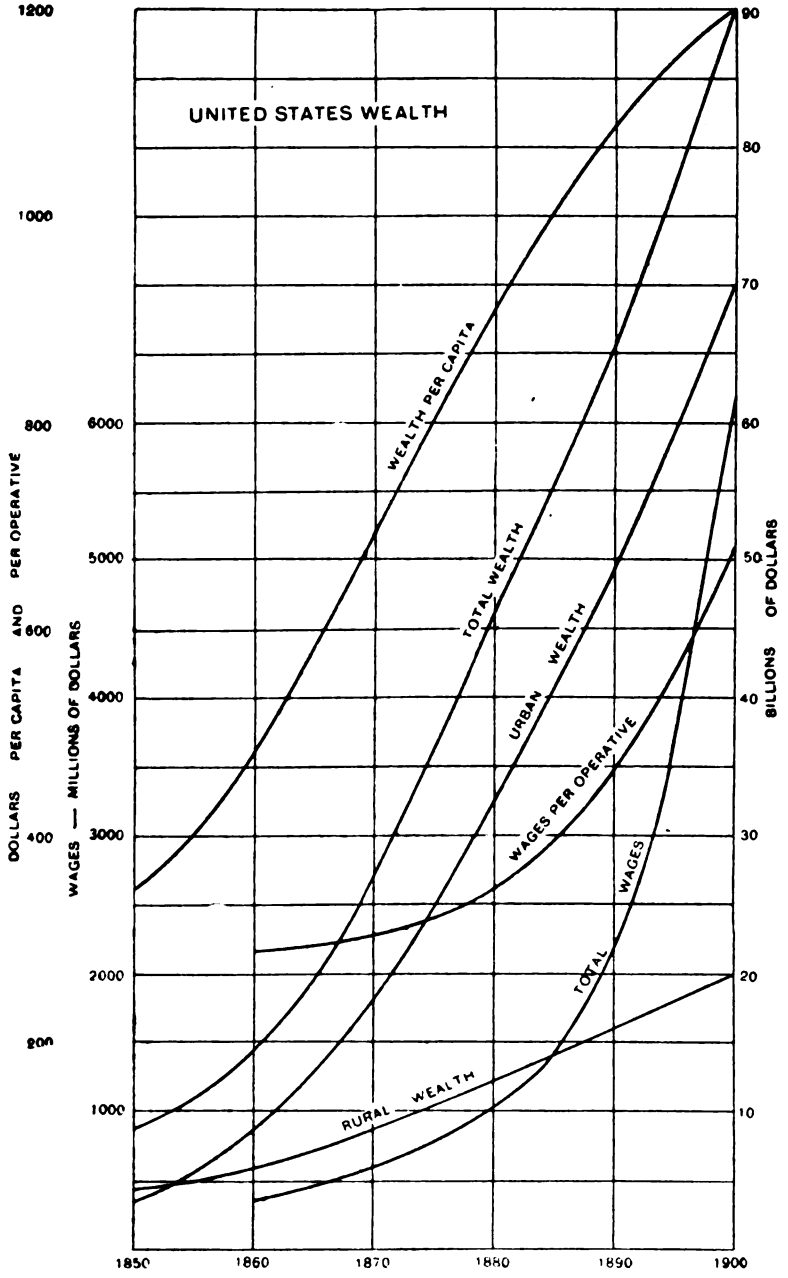

PLATE 3.

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doubled, increasing 128%, while population has gained only 52%. There are no signs of a let-up in this progress. Stationary and marine engines, while showing a lower rate of increase than locomotives, are yet gaining on population, giving more than 100% gain in the last twenty years.

Hand power, which in 1830 was about even with steam power, keeps even pace with population, being now only 14% of the total steam power. Horse power increases rather faster than population. The curve at present is very near a straight line, indicating a continued increase, without acceleration.

In Plate III are shown several curves representing the wealth of the United States. All of these curves show a continuous acceleration, except the curve of wealth per capita, in which the acceleration has been negative for the past twenty-five years. Since 1850, the total wealth of the United States has increased from $9,000,000,000 to $90,000,000,000, or 900%. Meanwhile population has increased from 23,000,000 to 76,000,000 or 230%. Thus the per capita wealth has increased from $365 to $1200, or 230%. That the latter has a negative acceleration is shown by the fact that while the increase between 1850 and 1870 was 100%, that between 1880 and 1900, an equal period, was only 31%. Zero acceleration would have made this latter figure 40%. The total wealth is seen to have risen almost coincidently with steam power, and is very closely proportional thereto. It may be shown that the former is by no means independent of the latter, for it is only as man's productive power increases above his consumptive power (to which state of affairs steam power has enormously contributed), that he is able to rapidly produce permanent forms of wealth, such as are largely represented by the figures given.

The curves for rural wealth and urban wealth crossed each other about 1853, with some $4,500,000 000 under each heading. Since that time, the latter has left the former far behind, being now about 75% of the total. While the former has a steady rate of increase, which will apparently be maintained indefinitely, the latter is advancing with enormous strides, with no signs of a stop. Wages are seen to be mounting with large acceleration, reaching at present upwards of $6,000,000,000 per annum, or some 7% of the nation's wealth. In 1860, with a wealth of $14,000,000,000, wages amounted to a total of $350,000,000, or 2.5%. The total has thus been multiplied by seventeen in the last forty years, and it has nearly trebled in ten years. Wages per operative show a steady increase, from $300 in 1860 to $675 to-day. This curve has an increasing slope, showing a rapid acceleration.

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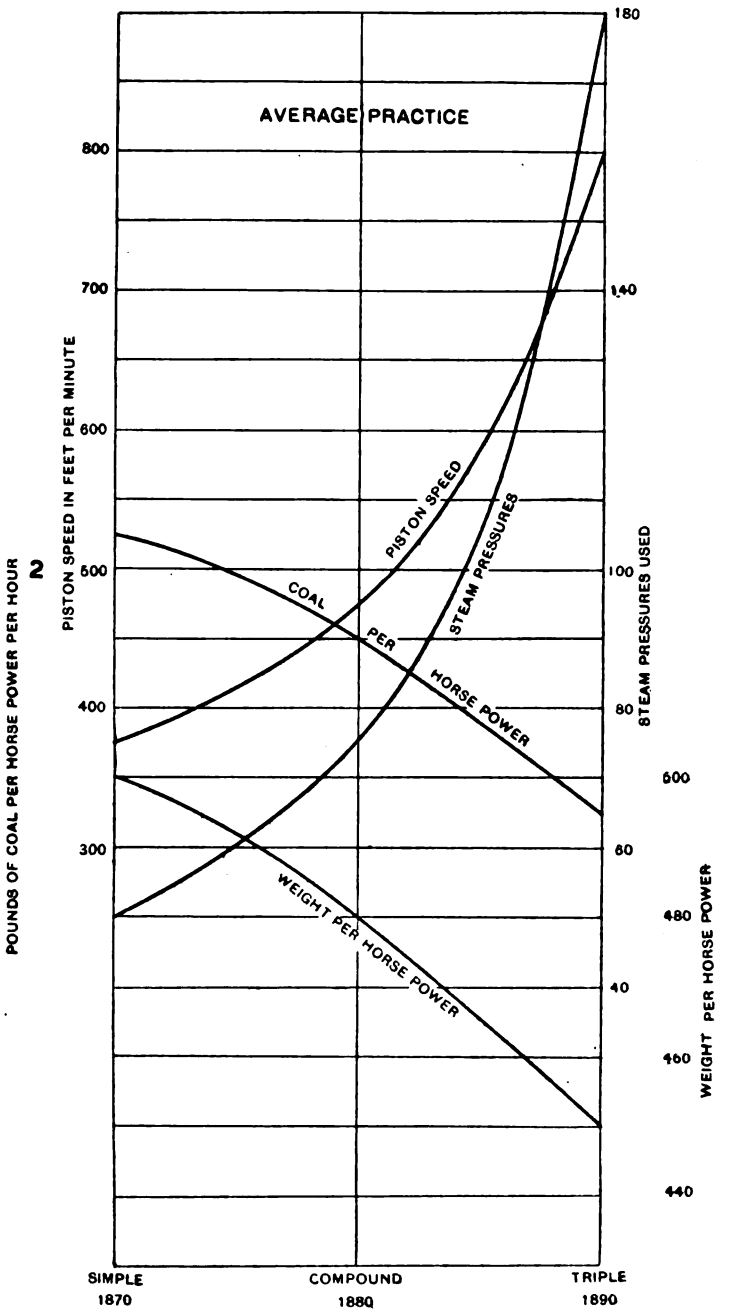

PLATE 4.

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Plate IV shows the general effects obtained by the introduction of the compound and triple-expansion engines. The high-water mark of the simple engine was reached about 1870; in 1880 the compound was in high favor, while by 1890 the triple-expansion engine was well established. The steam pressure curve is seen to have gone up rapidly, and the recent advent of quadruple-expansion engines in marine practice has shoved it up still higher. The weight of engine per horse-power is falling off, with increase in the stages of expansion; decreased size for a given power, under high pressure steam, is partly responsible for this, as is also the advance in materials of construction and methods of manufacture. The increasing complexity of design militates against this downward tendency, and the necessary thickening of cylinder walls and steam passages, incident to the use of higher pressures, has the same effect. The decreased cylinder condensation, due to sub-dividing the fall in temperature between initial steam and exhaust into a number of stages, has effected a saving in coal, the results of which are well shown in the curve. With increasing steam pressures, the speeds of revolution have increased, and the piston speed has rapidly gone up. It is now much more than double its value of a quarter of a century ago, and is apparently destined to increase for some time to come. Consequent upon this feature has occurred part of the reduction of weight per unit of power, previously considered.

As already mentioned these cases might be multiplied indefinitely, and a vast amount of data collected into the form of curves depicting the varying relations of progress with time. Enough has been presented, however, to show the enormous advances engineering science has made in this country during the past century, and particularly during the latter part thereof.

ELECTRIC DRIVE IN SIBLEY COLLEGE.

A committee consisting of Professors Ryan, Morris and Barr, has submitted to Dr. Thurston a report with recommendations upon the use of electric motors for power in the various shops and laboratories, as follows:

To eliminate long lines of connections now made by shafting, belting and rope drive, and for the purpose of flexibility in operation, by which any one or more of the several divisions of the mechanical equipment of the college may be operated inde-

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pendently of the others, it is proposed to recognize the following divisions in the Sibley College equipment :

1. a. Machine and wood shops.
   b. Machine shop extension, to occur in the old locker space.
   c. Motor drive for individual tools, motor connection designed as part of the tool.
   d. Individual drive for one of the present large tools.
2. Blacksmith shop.
3. Foundry.
4. a. Experimental Engineering Laboratories.
   b. Experimental Engineering Mechanician's shop.
5. Basement of East Sibley.

The motor requirements for these various divisions are as follows :

In all cases we would recommend that standard makes of "slow-speed" direct current 500-volt motors be purchased.

The "slow-speed" motors, on an average, operate at 60 percent of the speeds of "moderate-speed" motors, with a corresponding increase in first cost. An ample experience in practice in the last ten years has shown that these slow-speed motors are by far the cheaper in the long run. This advantage is gained by the smaller attendance, maintenance and repair costs that the slow-speed motor requires. In addition to this, an important item that contributes to the practical superiority of the slow-speed motor over its moderate-speed rival, is the smaller number of interruptions to the service it causes, because of being put out of commission for repairs at much longer intervals.

With these points in mind, we would recommend that motors be installed in the several divisions as follows :

1. a. Machine and Wood shops.
   One 50-H.P., 500-volt, 575 R.P.M., D.C. motor.
   b. Machine shop extension ; shaft drive.
   One 3-H.P., 500-volt, 1100 R.P.M., D.C. motor.
   c. Machine shop extension ; tools with self-contained motor drive.

In this section would be installed the motor-driven tools that Sibley College may buy in the near future, in which a motor forms an actual necessary part of each tool.

   d. Individual drive.
   One motor to drive the large lathe or planer as may hereafter be determined, independently of main shop drive.
   One 1-H.P., 500-volt, D. C. motor, speed not yet determined.

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2. Blacksmith shop.
   One 3-H.P., 500-volt, 600 R.P.M., D. C. motor.
3. Foundry, cupola fan, and tumbler drive.
   One 3-H.P., 500-volt, 1200 R.P.M., D. C. motor.
4. Experimental Engineering.
   a. Laboratory.
      One 15-H.P. motor, data not yet determined.
   b. Mechanician's shop.
      One 3½-H.P., 600 R.P.M., D. C. motor.
5. Basement of East Sibley.
   Drive for X. E. equipment and fan for ventilating east lecture room.
   One 20-H.P., 500-volt, 600 R.P.M., D. C. motor.

The equipment here proposed would supply all demands for motor drive that are immediately necessary, either for the practical purposes of economical, convenient and reliable power-supply for term and vacation times, or for shop instruction and illustrative purposes. For power supply to the various departments of Sibley College, this equipment would suffice for all present requirements, and allows, where necessary, for some increase in demands that the not very distant future is likely to develop. In the near future, if the funds can be spared for such purposes, there should be provided in the machine shop a motor drive equipment that illustrates the following variable speed electric motor drive system. This is known as the Teaser System.

The Teaser System makes use of a multiple-pressure source. The pressures of the source usually number six, giving approximately 50, 100, 175, 275, 375 and 500 volts. 500-volt D. C. motors are used. Their fields are excited from the 500-volt pressure. In bringing a motor to speed in this system by means of its controller, the armature is first connected to the 50-volt pressure, and after gaining the low speed corresponding to that pressure, the connection is made to 100 volts, where more speed is attained, and thus in succession connection is made to the higher and higher pressures, until the 500-volt pressure is reached, and the motor is running at normal highest speed. If some definite intermediate speed is desired, the connection of the armature is made to a lower pressure, corresponding to the drop in speed desired. Should a particular speed be desired that requires a pressure which falls between two of the source pressures, the limited adjustment thus required may easily be made by a change in the field strength of the motor.

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This system is exploited by the Bullock Electric Co. for all variable drives in shops, and for printing presses, etc. There can be no doubt of its great practical importance in many instances, owing to the elimination of the rheostat, and the provision of an indefinite number of definite speeds to which the motor may be quickly and accurately brought, running forward or backward.

It is desirable that Sibley College soon find some means for the practical illustration of this system of variable speed drive. It would cost somewhere between $500 and $1,000 to apply this Teaser System. Should we find the means in the future for the supply of the multiple pressure source, this Teaser System, for instruction purposes, could be applied with advantage to driving a planer, a screw-cutting, or similar tool, the larger sizes being preferred, in which the motor would automatically change its own speed for a quick return and a slow forward drive.

Attention should be called to the fact that the 50-H.P., motor above advised for the main machine shop drive was bought by Sibley College recently, and has now been delivered. It is proposed to install this motor temporarily in the basement of East Sibley for drive during the present year, taking the place of the rope-transmission, the removal of which was made necessary by the new Sibley building.

Mention should also be made of the motor-driven Sensitive Friction Drill that has been offered for exhibit in the machine shop by Hill, Clarke & Co., of Chicago. This tool will be very useful to illustrate to students in the machine shop the use of motor-driven tools in out-of-the-way places when the tools are small, or in the main machine shop of a factory where large tools have to be freed from belt obstruction, and for the driving of portable tools.

Use of Alternating-Current Motors.

If there were at hand an ample source of polyphase current, the committee would have recommended the purchase of induction motors in each instance where constant speed is required. Such current is not available at the present time, and may not be before a number of these motors have to be secured and put into operation. For constant speed drive, when the load does not momentarily vary excessively, the induction polyphase motors are preferred to the D.C. motors because of their greater simplicity of construction, requiring less attendance and entailing less maintenance and repair costs, providing at the same time a greater continuity of service.

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Order of Installation.

First. We would recommend that the motors for the Blacksmith shop, Foundry, and X. E. Mechanician's shop be purchased and installed at once.

Second. Next in order should be installed the electrical drive for such tools as are to be placed in the machine shop extension, and which are not to have motor drives as inherent parts.

Third. Tools having inherent motor drives should then be added to the shop extension.

Fourth. The Teaser System should be applied to a portion of the shop extension equipment.

Fifth. An individual motor should be mounted in the main machine shop, to drive a large lathe or planer.

By the time the foregoing has been accomplished, it is reasonable to assume that the authorities will have established a modern power-plant suited to the needs of the University. This plant will furnish both continuous and polyphase alternating currents so that the sixth and final addition to our motor drive, as planned in this report, can then best be made.

Sixth. The transfer of the 50-H.P., motor from the basement of East Sibley to the machine shop, where it is to operate permanently as the main drive, should occur. The motors for the Experimental Engineering Laboratory and for the basement of East Sibley should then be purchased and installed. If this is done after the establishment of the new University Power Plant, and such plant furnishes an ample supply of polyphase current, which should surely be the case, then the two last motors should be of the polyphase induction type.

STANDARDIZATION OF EXTRA HEAVY PIPE FLANGES.

Steam pressures varying from 100 to 250 pounds pressure entered into engineering practice about the year 1889. For pressures less than 100 pounds there had long existed confusion regarding standards for flanges of pipe, fittings and valves. A schedule of standard flanges was adopted July 18, 1894, by a committee of the Master Steam and Hot Water Fitters' Association, a committee of the American Society of Mechanical Engineers, and the representatives of the leading valve and fitting manufacturers of the United States. As the use of high steam pressures

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became more general there came into existence so many different diameters, thicknesses, drilling circles and number of bolts for flanges on fittings, valves and pipe for extra heavy pressures that manufacturers could not safely keep stocks of goods, and mill architects and engineers were greatly delayed at times in making up specifications for contemplated work on account of time taken to find out what the different manufacturers could or would furnish.

Recognizing the need of a standard for extra heavy flanges, an invitation was issued to the leading valve and fittings concerns of the country to meet and consider this subject. In response to this invitation several of the largest concerns sent representatives to a meeting at New York City, April 24, 1901. At that meeting a committee was chosen to formulate a standard.

The committee had various sessions and submitted to the manufacturers interested the following recommendations and schedule for standard at a meeting held in New York City, June 28, 1901:

1. Multiples of four for drilling.
2. Drilling should straddle axis.
3. Bolt centers not to exceed 3⅝" except on 2½" size. Committee at first proposed 8 ⅝" bolts, but sample elbows and flanges

Size of pipe. Inches.	Diameter of flange. Inches.	Thickness of flange. Inches.	Diameter of bolt circle. Inches.	Number of bolts.	Size of bolts. Inches.
2	6½	⅞	5	4	⅝
2½	7½	1	5⅞	4	¾
3	8¼	1⅛	6⅝	8	⅝
3½	9	1 3/16	7¼	8	⅝
4	10	1¼	7⅞	8	¾
4½	10½	1 5/16	8½	8	¾
5	11	1⅜	9¼	8	¾
6	14½	1 7/16	10⅝	12	¾
7	14	1½	11⅞	12	⅞
8	15	1⅝	13	12	⅞
9	16	1¾	14	12	⅞
10	17½	1⅞	15¼	16	⅞
12	20	2	17¾	16	⅞
14	22½	2⅛	20	20	⅞
15	23½	2 3/16	21	20	1
16	25	2¼	22½	20	1
18	27	2⅜	24½	24	1
20	29½	2½	26¾	24	1⅛
22	31½	2⅝	28¾	28	1⅛
24	34	2¾	31¼	28	1⅛

were drilled and bolted together and it was found that 8 ⅝" bolts interfered with inserting bolts.

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4. Distance from center of bolt to edge of the flange should always equal or exceed the diameter of bolt plus ⅛" for 9" valves and under, and diameter of bolt plus not less than ¼" for sizes larger.

The bolt circle diameters as above stated will allow the use of calking recess on pipe flanges provided such device is specified.

The schedule presented was unanimously adopted by the manufacturers present, and Jan. 1st, 1902, was the date set for adoption of the same.

A limited number of the schedules will be printed by the committee, and copies can be obtained of the secretary, J. F. O'Brien, P. O. Drawer No. 66, Station A., Hartford, Conn.

UNIVERSITY OF CHICAGO CENTRAL POWER PLANT.

An extensive heating, lighting and power system is being installed on the Campus of the University of Chicago. A central power-house is now in course of erection, and from it a system of tunnels will run to the seventeen buildings on the Campus, carrying the heating mains and the cables for the electric lighting and power. There are to be three direct-connected power units, consisting of Westinghouse electric generators in sizes of 350, 250 and 60 kilowatts, coupled to Ball engines of 600, 400 and 80 horse-power capacity, respectively. The buildings will be lighted on the 220-volt, three wire system, and a 100-kilowatt compensator at the power house will serve to balance the load. Later there is to be a 20-kilowatt compensator installed for use with the smallest generator, on night loads. The plant will supply a total of about 12,000 incandescent lamps, and about 15 arcs for outdoor lighting. About 90-horse power in motors will be used in the different buildings for ventilating purposes, and a 50-horse power motor will drive a forced-draft apparatus. A number of electric elevators, as well as all the motors for laboratory and other purposes that are now installed, will be operated from the main plant. The boiler plant will consist of ten 150-horse power Titusville water-tube boilers. It is expected that the system will be in full operation early in January.

—*Western Electrician.*

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THE SIBLEY JOURNAL OF ENGINEERING.

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THE SIBLEY JOURNAL OF ENGINEERING,
ITHACA, N. Y.

OUR frontispiece this month represents the condition of the addition to the Sibley College, at noon, December 3d. It will be noticed that the masonry is now nearly completed. At the present writing, some of the roof-plating has been put in place, and doubtless before our next issue appears the whole building will be covered in.

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THE demand for technically educated men, and especially for those who have had some practical experience in the great industries—for those competent to teach in lines similar to those of the Sibley College departments, carrying out elsewhere Sibley College methods, continues very large and far in excess of the supply. The Director is constantly receiving applications which he can find no suitably prepared men to accept. Toward the end of the academic year, the indications are that the call for alumni of Cornell to take positions on the faculties of other colleges, especially in the west and south and on the Pacific coast, will again be far greater than can be met. Students and alumni who are ambitious to enter the most honored branch of their profession, professional education, are advised to earnestly seek that combination of scientific and practical knowledge to which every successful teacher in the professional institution owes his success so largely. A peculiar talent is demanded of such men ; but the man who exhibits this talent, and the characteristics appropriate to the exalted position assigned the professional man in this department, gains a position of honor seldom the prize of his colleague who is in the business for gain, solely.

Department Notes.

The *Electrical World and Engineer*, in reviewing "Moteurs Synchrones à Courant Alternatifs" by André Blondel, makes particular mention of the fifth chapter, which "describes experimental researches on synchronous motors, referring at length to the interesting researches of Professors Bedell and Ryan on the determination of the angle of lag or lead."

The synchronous motor results of Professors Bedell and Ryan in their paper on "Action of a Single-phase Synchronous Motor" were published in the March, 1895, number of the *Journal of the Franklin Institute*. The object of the investigation that led to the results given in this paper was to compare the electrical and mechanical phase reactions of synchronous generators and motors existing in actual performance with those deduced from theory as given by Professor Ryan in the SIBLEY JOURNAL OF ENGINEERING, Vol. VIII, number 8, May, 1894. The experimental work was performed most skilfully by Messrs. Lyman and Huitt, students in electrical engineering in 1894. The results obtained

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agreed very well with those deduced from the theory. This experimental investigation to check theoretical results was greatly assisted by the mechanical phase indicator devised by Professors Bedell and Moler.

Regarding the actual power used by the University, a thesis test of H. L. Gilbert and E. D. Struven, last year, gives considerable information. The total number of incandescent lights in use was 3716, while the new buildings now going up, and those to be erected shortly, will bring this total to 5,500. Reckoning these at 50 watts each (about 3 watts per candle), the power required is $\frac{5,500 \times 50}{746} = 369$ horse-power.

The sixteen arcs, at 650 watts, consume 14 horse-power. The incandescent lights, however, are not all in use at any one time, and experience has shown that the normal maximum may be carried on 137 horse-power. Ventilation and miscellaneous power purposes, at present, account for 68 horse power, while 34 additional will be required in the new buildings.

The Dynamo Laboratory has two 50 horse-power motors, but these are never heavily loaded. Sixty horse-power would seem to be a fair assumption for the two. Shops and Mechanical Laboratory require, at present, 35 horse-power, while impending additions will need six more. Thus the grand total of power actually required at the present time becomes 314 horse-power, to be shortly increased to 420. With all lights in use, and full power taken by the Dynamo Laboratory, these figures would be increased to 467 and 626 respectively.

Personals.

'89 E.E., '90 M.M.E. Louis Benedict Marks is the subject of a sketch in the *Electrical World and Engineer*, in its series on "Electrical Engineers of the Day." Graduating as B.S. from New York College in 1888, he entered Sibley, making a specialty of the study of the arc-light. "In a paper read at the 1890 meeting of the American Institute of Electrical Engineers in Boston, entitled 'Life and Efficiency of Arc Light Carbons,' he presented the results of original investigations in the Physical Laboratory of Cornell University, made by him under the direction of Dr. E. L. Nichols. During this period Mr. Marks devised a small voltameter which furnished the subject of a paper pre-

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sented before the American Institute of Electrical Engineers by Professor Harris J. Ryan. . . . . Mr. Marks is doubtless best known from his invention of the enclosed arc lamp. This was based upon the discovery that the life of the carbons is greatly extended by enclosing them in a small sealed globe, and the increased time-limit for permitting chemical combination of the dissociated carbon particles results in an arc of an entirely new character. While the ordinary open arc operates at 45 volts and 10 amperes, it was demonstrated that an inclosed arc can be efficiently operated at double this voltage, and at half this current. It was also found that a pair of carbons, which, in the ordinary lamp would burn eight hours, will last 150 hours when operated under the above conditions. The General Electric Co. purchased the Marks enclosed lamp patents last year, and has retained Mr. Marks as a member of its expert staff.

"Mr. Marks is a member of the American Institute of Electrical Engineers, the Societe Internationale des Electriciens, the National Electric Light Association, and several other similar bodies."

BOOK REVIEW.

Nature's Miracles: Familiar Talks on Science. Vol. III. *Electricity and Magnetism.* By ELISHA GRAY, LL.D. New York: Fords, Howard & Hulbert. Cloth, 60 cents, net.

In this volume on Electricity and Magnetism the author begins at the beginning, and gives a succinct history of the science of these two closely interrelated forces, neither of which was of great practical value to the industrial world (except the magnetic needle in navigation) until it was discovered that magnets could be made by electricity, after which the use of the two forces together has advanced by leaps and bounds, so that men dare not prophesy any limit to their practical applications.

Professor Gray "tries to give such a simple exposition of the phenomena and applications of these forces that the general reader may get a clear elementary understanding of the subject so far as it is known," and he succeeds admirably. His space is limited and he has room for very few diagrams, but his explanations are lucid, and the average man, who ought to understand the principles of these every-day wonders, will find delight in following his agreeable, but exact and accurate, accounts of them. Electrical currents, generators, and atmospheric conditions; the measurement of electricity; the various interesting details of the telegraph and its working, including the marvels of multiple transmission; the telephone and how it talks; divers curiosities; the telautograph; submarine and wireless telegraphy; and finally a series of chapters on the use of electromagnetism in manufacturing processes, as at Niagara Falls, are among the topics treated.

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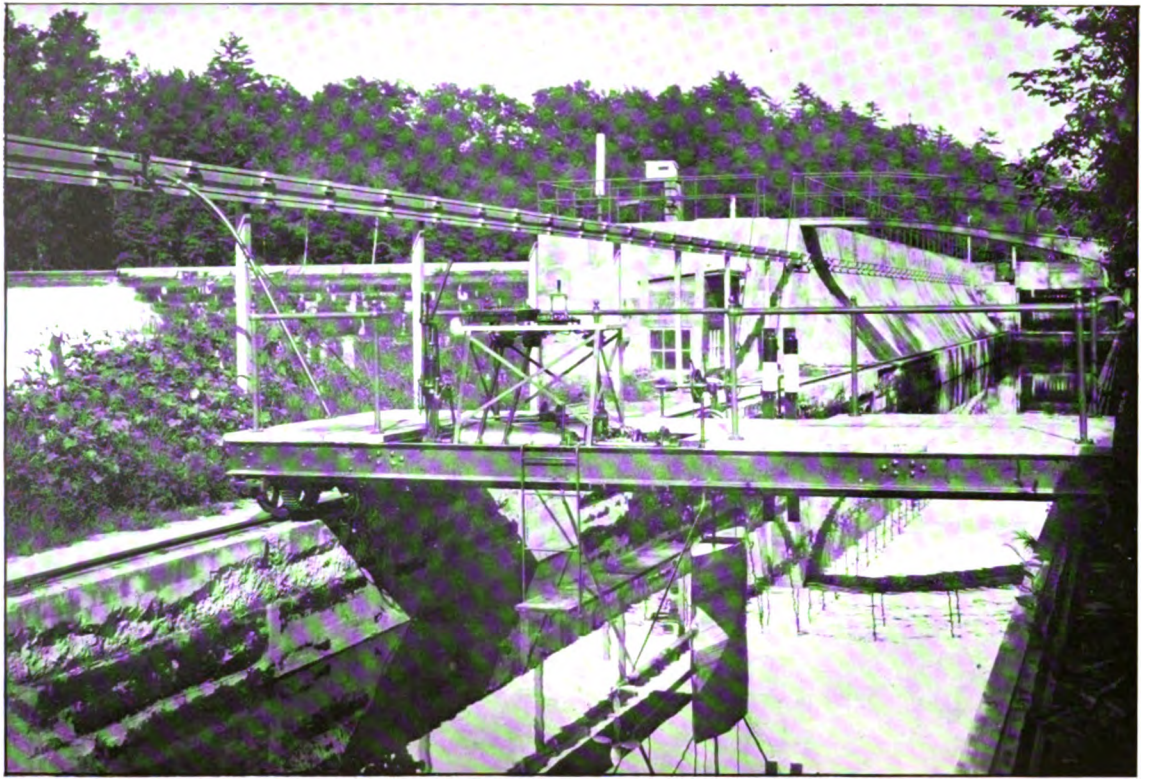

THE CORNELL UNIVERSITY EXPERIMENTAL CANAL.

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THE SIBLEY JOURNAL OF ENGINEERING.

VOL. XVI. JANUARY, 1902. No. 4.

IN CORNELL UNIVERSITY.

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislature of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

THE EDUCATION OF MECHANICAL ENGINEERS AND CHEMISTS IN THE HIGHER TECHNICAL SCHOOLS OF RUSSIA.*

BY M. SSEREBROFFSKY AND G. VON DOEPP.

At present there are in Russia six high schools with divisions for machine construction and chemistry: the Technological Institutes in St. Petersburg and in Cracow, the Imperial Technical School in Moscow and the Polytechnic Institutes in Riga, Kiew and Warsaw. The aim and purpose of these institutions is, to give the required theoretical and practical instruction to the youths who wish to devote themselves to engineering and to railroad service. Besides this, the archduchy of Finland has a single polytechnic school in Helsingfors, which we will not include in our observations, as it occupies an independent position and is essentially foreign in its character and serves the needs of Finland almost exclusively.

Among the institutions named, are two older ones (the Technological Institute of St. Petersburg and the Technical School in Moscow), which were originally established as trade schools, and

* Translated by R. E. Mueden from *Zeitschrift des Vereines Deutscher Ingenieure.*

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by gradual evolution have developed into High Schools, like the corresponding German institutions. For this reason they are in some ways cramped for room and are therefore at a disadvantage with some of the later schools which were brought into existence fully developed High schools, and can make use of the experience of the older institutions, in building and meeting the advance of the times.

The other technical institutions of this kind follow in order of date of founding: the Polytechnic Institute of Riga, the Cracow Technological Institute and the Polytechnical Institutes in Kiew and Warsaw, the last two being open only since 1898. Finally the Tomsk Technological School and the St. Petersburg Polytechnical School are to be mentioned: the former was opened in the Fall of 1900 while the latter is still building and cannot be opened before 1902.

The Technological Institute in St. Petersburg which has served as a model for the other schools was founded in 1828 by Emperor Nicholas I, and opened in 1831. At that time it received youths from 13 to 15 years of age without special preparation and instructed them in various trades and some few branches of theoretical work, the course lasting six years.

The rapid development of technical learning made demands for a higher standard of education and led to a fundamental rearrangement of the institution which began in the year 1868. The most essential changes consisted in shortening the course to four years and the division into two courses, one for mechanical engineering, the other for applied chemistry. Besides this, the questions of the title or degree and privileges of the graduates, the rank of professors and instructors, and the amount of yearly expenses were decided.

It is interesting to note, that since 1877 the school has published annually the "Reports of the Technological Institute," which contain scientific articles by the Professors and Instructors.

The rules holding to-day originated in their essentials in 1878. At that time the course of instruction was lengthened to five years, not more than 125 students being allowed to enter the first year.

The lengthening of the course of study permitted the students of the fifth year to prepare themselves for special branches of work. From those who wished to devote themselves to manufacturing, was demanded the design and planning of a complete factory, just as in the Central Schools of Arts and Industries in

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Paris. Those who wished to go into the railway service were required to design a locomotive. Besides this, in the fifth year, exercise in practical mechanical construction was given particularly in bridge building.

With the broadening of the curriculum the privileges of the graduates were extended ; they received from 1878 on, the degree of Technical Engineer in the particular branch which they elected. They also were authorized to erect factories and mill work, dwelling houses, to do work which came under the Department of Civil Engineering, and to hold office in that bureau.

The St. Petersburg Institute of Technology has belonged since its founding to the Ministry of Finance. To secure a better system of teaching it was placed under the control of the Bureau of Education in 1881. In the year 1887 a new regulation affecting graduates was introduced, by which they were compelled to stand State Examinations. The remaining special schools of the Russian Empire, the Mining Institute, the Forestry Institute, the Institute of Civil Engineering and the Institute of Architecture do not require this examination. The examinations are held once a year under a committee composed of members of the instructing staff and whose chairman is selected by the Minister, usually outside the faculty. The examination is oral and the questions concern chiefly a thesis or design made by the student.

The regulations of 1878 and 1881 are still in force though somewhat altered to suit the progress in the different departments. In this way the instruction in Electrotechnics with practical work was introduced in 1892, and in 1898 the engineering laboratory was founded.

The curriculum is divided as follows :—

1ST YEAR :—Religion, higher mathematics, (analytical geometry, differential calculus and higher algebra), descriptive geometry, physics, chemistry, theoretical mechanics, elementary geodesy, mechanical drawing, architectural drawing and free-hand drawing.

2ND YEAR :—Higher mathematics, (differential and integral calculus, for the mechanical course only), analytic mechanics (dynamics of rigid bodies) theoretical mechanics (dynamics of systems), physics with laboratory work, strength of materials and machine details, applied mechanics, building construction, architectural and building drawing, mechanical drawing, with mineralogy, geology and chemistry for the chemical course.

3D YEAR :—(a) For all courses—

Thermodynamics, technology of metals, heating and ventilation, boiler study and electrical measurements.

(b) For mechanical course only :—

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Applied thermodynamics, theory of probabilities (elective), hoisting machinery, graphical statics, hydraulics, steam engines, metallurgy, construction of machine details, building construction.

(c) For chemical course :—

Organic chemistry, technology of metals, botany and bacteriology, steam engine construction (elective), work in laboratory and practice in building construction.

4TH YEAR :—(a) For all courses—

Electrical science (elective), electrotechnics, technology of textile fabrics, water works, physical laboratory.

(b) For mechanical course :—

Mechanics of construction, mechanic arts (foundry work, metal working, rolling mills, blowers, and steam hammers), technology of wood, locomotive construction, boiler design, water motors, steam engines, and practical work in factories during summer.

(c) For chemical course :—

Technology of organic compounds (illuminating gas, naptha, fats and oils) paper manufacture, technology of food stuffs, dyeing and bleaching, technology of dye stuffs, ceramics, practice in machine construction (boilers), electro chemistry, designs for factories, work in chemical laboratories, practical work during summer in factories.

5TH YEAR :—(a) Section for machine design—

The students in this course design a roof truss and a bridge down to the smallest details, plan a factory (iron or steel works, foundry, rolling mill, or the like), a water works, an electrical plant or a locomotive. The time spent in summer is devoted to the branch chosen by the student. Those who choose railroad engineering must show service on locomotives. Besides this the students work in the shops in mechanical electrical and engineering laboratories on set systems.

(b) For chemical course :

After the student has become familiar with a chemical factory duriug the summer he devotes himself to the design of factory plans (naphtha refinery, sugar refinery, paper mill, brewery, distillery, etc.,) and with work in the laboratory.

Besides the courses mentioned, instruction is given in the French, German, and English languages, in industrial book keeping (accounting) factory legislation and hygiene.

Among the characteristics of the Institute are the compulsory attendance at recitations and the required shop work. Furthermore, students must pass a spring examination in order to enter the next higher class; no student being allowed to stay more than two years at most in one course, and to stay more than one year in course I, he must prove illness The curator of the St. Petersburg Department of Instruction can in special cases grant permission to stay three years in one course. Besides the regular examinations there are held in all fundamental branches (mathe-

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matics, mechanics, physics and chemistry) a kind of oral examination in which problems are worked out at the blackboard.

The institute originally favored shopwork above all other things, as its name "Practical Technical Institue" indicated, though later on this was subordinated more and more. The work done in the shops is meant to take the place of the year of practical experience demanded for admission to certain German high schools. Besides the shops there are laboratories for mechanical work and engineering science. The students in the chemical course are similarly provided for. From the general laboratory they go into one of the technical laboratories of which the institute possesses four, a separate laboratory for inorganic work, organic work, dye work, and fermentation processes. Among the means of instruction may be mentioned the magnificent library and various collections of machinery and models, among which there is a collection of fragments of exploded boilers, begun 25 years ago.

Of the 234,323 rubles* appropriated each year for the support of the institute, 111,000 rubles† are paid the instructing staff and officials, consisting of 13 professors, 4 assistant professors, 42 instructors and laboratory instructors, one inspector and 5 assistants to enforce order.

Of late years more than 100 students graduated each year as the following statistics show:

Year.	Total Grads.	Mech. Dept.
1897	144	98
1898	130	99
1899	113	98

Up to 1899, 3,674 students had taken the entrance examinations and the registration at New Year's of 1900 was:

	Courses.	
Year.	Mechanical.	Chemical.
V	102	25
IV	136	17
III	182	16
II	243	
I	295	
Total	1016	

The reason for the small number of chemical students is that the demand for mechanical engineers is greater just now than that for chemists, besides which the laboratories have long needed the thorough remodelling which was begun in 1898.

*$120,676. †$57,165.

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The students pay only 50 rubles ($25.75) a year for tuition, which is in reality only a laboratory fee, and in order that poorer persons may avail themselves of the courses, the government and private persons have founded scholarships, besides which the Institute admits 90 free students. On the grounds of the Institute is a large dining hall run by a co-operative society, which furnishes good board for 600 students.

As the applications for admission exceeded the allowable number, (125, or after remodelling 250), entrance examinations were instituted which all matriculants were required to pass—having first fulfilled the requirements that they should be graduates of a Russian grammar school or High school.

The candidates are required to write a composition in Russian on a given subject and then are examined orally in physics, geometry, algebra and trigonometry. The graduates of the mathematics courses of universities are allowed to enter course II, others being allowed to enter course I without examination. The lectures begin usually on Sept. 2, and close in the middle of April, when the examinations begin, lasting till the end of May.

Next in chronological order comes the Imperial Technical school of Moscow, which was founded in 1832. Originally intended to give the 300 inmates of the Foundling asylum a trade education, it developed into a High School. It had departments for chemistry, machine construction, and architecture, the curriculum being divided into 6 years. Practical work was made very important and even now the workshops are considerably larger than those of St. Petersburg, constituting a complete machine factory, which takes orders from outside for steam engines, turbines and machine details.

In 1896 the Imperial Technical School was remodelled on the plan of the Technical Institute of St. Petersburg, the course being shortened to 5 years. The graduates of both departments received the degree of Technical Engineer. The curriculum is very similar to that of St. Petersburg; it differs only in the matter of shopwork. For instance, those in the mechanical department, before entering their second year, work during August and September 6 hours a day at wood turning, and in the analytical chemical laboratory, where they perform qualitative analyses. In the second and third years geodetic practice is held from the 1st to the 13th of June. Before entering the third year the students of the Mechanical Department must work 6 hours a

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day in August and September in the foundry, blacksmith shop, pattern shop and locksmith's shop: those of the Chemical Department working in the analytical laboratories. At the end of the third year, work is required of the mechanical students in the locksmith's shop and in the machine shops, and in the factory of the school for those in the chemical course.

The Polytecnic Institutes of Riga, Kiew, and Warsaw have more departments; that of Kiew has four, Mechanical Engineering, Chemistry, Agriculture and Architecture. That in Riga has six departments, Agriculture, Architecture, Chemistry, Mechanical Engineering, Engineering Science and Commercial Science. This school differs from the others in that it was founded and supported by Municipal and State Corporations with the German Technical High Schools as a model, and introduced the instruction of the German language. Lately this institution has undergone some changes; the government now makes an annual appropriation and has also furnished funds to build a new chemical laboratory. The graduates are given the same privileges as those of other institutions, but they are required to accept certain reforms, notably the introduction of Russian as the language of instruction.

The mechanical and chemical curriculum of both the Institute of Kiew and that of Warsaw are identical. Besides the regular instruction, practice in designing and work in laboratories is given. The curriculum is divided into four years and there are chairs for regular and associate professors; in Kiew 23 and 12, and in Warsaw 17 and 8, respectively. Instructors direct the practical work of the students.

Both Institutes are under the authority of the Ministry of Finance. The entrance requirements are the same as those of the other Technical schools, that is, they demand the diploma from some High School and the passing of examinations.

The several departments bestow upon their graduates the title of Technical Engineer (Mechanical or Chemical Department,) of Constructing Engineer, and of Scientific Agriculturist. The engineers are accorded the same privileges as those from the Technological Institute of St. Petersburg.

The statutes of the two new Institutes in Warsaw and Kiew differ in two points from those of the Technological Institute of St. Petersburg in the introduction of Deans and the requirements of an advanced degree for appointment to a professorship. The St. Petersburg Institute had from the beginning a Dean who had

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charge of the elective curriculum. Later he was replaced by an assistant to the Director, who was to form the means of keeping the student-body and faculty in touch. In Warsaw and Kiew there are as many Deans as there are Departments. They represent their faculty, direct the instruction, and in conjunction with their staffs decide questions relating to their Departments.

Besides the higher institutions mentioned, there is another which gives the same education as do the Technology and Polytechnic Institute,—the Mining Institute of St. Petersburg, the oldest technical school in Russia. It was founded in 1773 as a Mining School with a four year course, and variously changed; to-day it has a department for mining and another for metallurgy.

The technical high schools are: The Institute of Civil Engineering and Institute of Constructive Engineering. The first was founded in 1809 and was at first of military character, the graduates leaving with the rank of officers and the degree of Engineer. Since the introduction of railroads, the Institute educates men for the direction and building of railroads. With this as a model the present Institute of Architecture was founded under Emperor Nicholas I and the graduates receive the title of Constructing Engineer or Architectural Engineer.

The education of Electrical Engineers is undertaken by the Technological Institute and an Electro-chemical Institute intended originally for the service of the State Telegraph Bureau, but now conducted upon a broader educational plan, making it much like the other schools.

At the present time there is building in St. Petersburg a new Polytechnical Institute to be under the charge of the Ministry of Finance. It is to have four departments, Electrical Mechanics and Electro Chemistry, Marine Architecture, Metallurgy and Mercantile Science. The establishment, planned for 1500 students, is just outside the capital and has railway communication. On the other hand, as noted, the Ministry of Education opened a Technical School in Tomsk in 1900 to develop the industries in Siberia. This school was originally planned for Mechanical Engineering and Chemistry but will probably add departments for Railroad Engineering, Electro-technics, Mining, Metallurgy and Construction. In 1900 an advanced school of Mining and Metallurgy was founded in Jekaterinoslaw to promote the mining industries of South Russia.

A number of these Technical Schools are being enlarged, for instance the Institute of Architecture, for which 200,000 rubles ($103,000) have been provided.

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The Technical Institute of St. Petersburg received 905,000 rubles ($466,075) for the building of laboratories and the enlargement of lecture halls and draughting rooms; the Institute of Cracow 250,000, ($128,750) and the Moscow School 600,000 rubles ($309,000). This will make it possible to admit double the number of students, so that in the year 1902 the total will be 1200 in Technological Institute and 900 in Moscow instead of 500.

The crowding to technical schools in Russia is enormous, as is shown by the following tables which compare the Russian and French schools.

TABLE I.

Name of School.	Applicants	Admitted
Technological Institute of St. Petersburg	1011	186
Mining Institute	943	98
Institute of Civil Engineering	706	137
Institute of Architectural Engineers	358	81
Electrotechnical Institute	224	53
Moscow Technical School	373	150
Technological Institute of Cracow	375	167
Polytechnic in Riga	356	258
École Polytechnique	1269	225
École Centrale des Arts et Manufactures	721	224
École des Mines	129	25
École des Ponts et Chaussées	91	20

TABLE II.

Name of School.	Number of Teachers.		
	Professors	Instructors	Total
1) Technological Institute of St. Petersburg	17	42	59
2) Technological Institute of Cracow	13	46	59
3) Technical School of Moscow	16	40	56
4) Mining Institute of St. Petersburg	18	32	50
5) Institute of Civil Engineers of St. Petersburg	14	94	108
6) Institute of Building Engineers of St. Petersburg	7	46	53
7) Electrotechnical Institute of St. Petersburg	7	39	46
8) Riga Polytechnic School	30	38	68
9) Warsaw Polytechnic School	25	—	—
10) Kiew Polytechnic School	35	—	—

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TABLE II (Continued.)

	Number of Students.				Applicants for Admission	Admitted	Annual Expenses
	Dept. of Machine Construction.	Dept. of Chemistry	Other Departments	Total			Rubles*
1)	958	50	—	1016	1058	291	316967
2)	635	58	—	685	355	257	260450
3)	713	142	—	855	492	230	327493
4)	—	—	527	527	1158	111	182958
5)	—	—	885	885	800	170	250000
6)	—	—	316	316	326	70	102495
7)	—	—	196	196	425	86	101168
8)	355	324	820	1499	496	306	271700
9)	194	110	155	459	611	275	180125
10)	—	—	—	—	—	195	229000

* The ruble is worth 51.5 cents.—Editor.

Dean Alderson, of the Armour Institute, of Chicago, reporting upon the great technical schools of Germany, says: "More theoretical than the Briton, more practical than the Teuton, the American can in efficiency, excel either. This characteristic is reflected in our technical education. Our schools teach the scientific basis of engineering better than the Germans. Technical education in this country is still in its infancy. Every great center of population should have its high-grade technical college; every industry should have its own trade-school; manual training, elementary science-work and drawing should be essential parts of the public school system from the kindergarten up. No bill for education can be too expensive if the money is judiciously expended for technical instruction. If our country is to become and remain a world-power, our plain duty is to care for the technical education of all our people."

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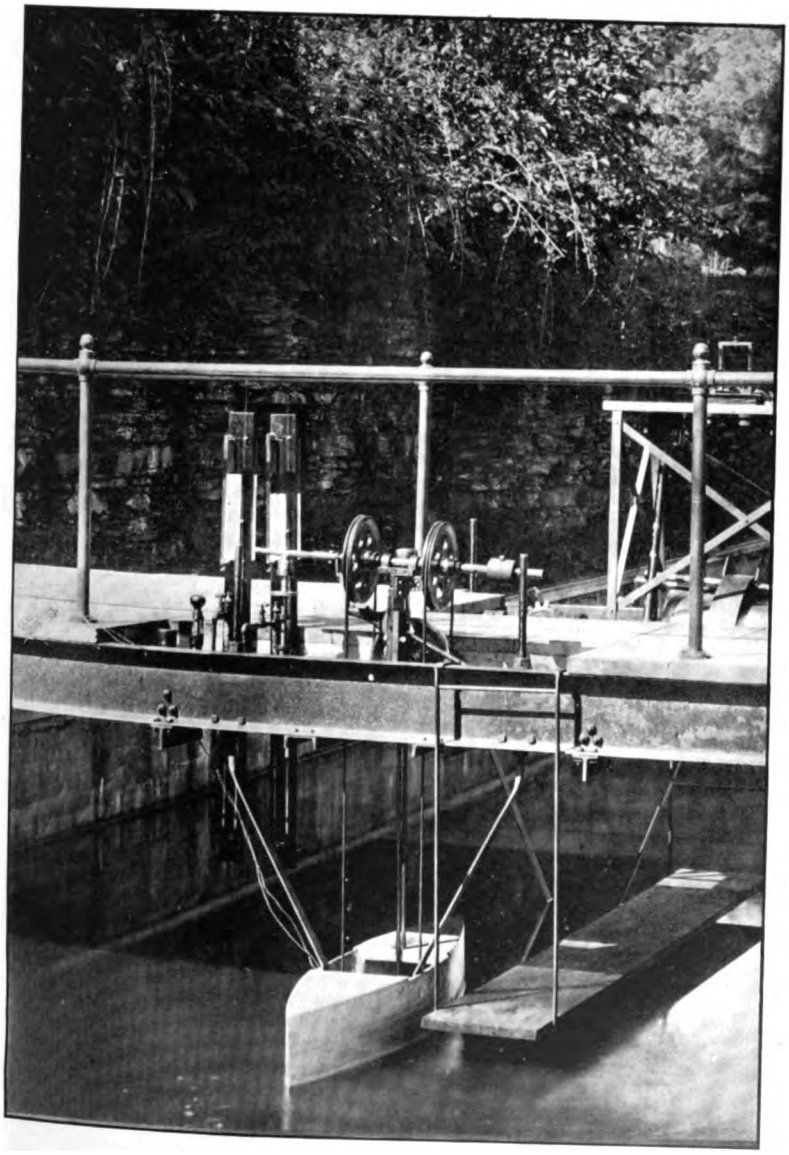

THE CAR AND FLOAT.

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THE EQUIPMENT OF THE CANAL OF THE HYDRAULIC LABORATORY OF CORNELL UNIVERSITY FOR EXPERIMENTAL WORK ON THE RESISTANCE AND PROPULSION OF SHIPS.

DR. WILLIAM F. DURAND.

The new hydraulic laboratory of Cornell University installed in charge of the College of Civil Engineering possesses among other features a canal or tank about 340 feet in length by 16 feet wide and 10 feet deep. It is in part excavated through the shaly rock which prevails in the locality, and in part formed by walls of a special mixture of concrete. The surfaces of the canal wall are all faced with a layer of silica-cement from two to three inches in thickness.

The canal is provided with water from the reservoir above, through double shut off gates and an intermediate lock or measuring chamber. Once filled the water is quiescent and the level may be maintained where desired by an adjustable weir at the western end.

At the present time the canal is open to the weather. It is to be hoped that in the near future means may be found for covering it over and thus greatly extending the facilities for work. Through the courtesy of the College of Civil Engineering the facilities provided by this canal are open for the use of the School of Marine Construction for experimental research along lines of importance to this field of engineering work. The two chief lines of work which can be carried on in such a canal and which are of value to the science and art of marine construction are those relating to the resistance of ships and to their propulsion. The equipment thus far installed consists of the following leading features:

(1) A carriage or truck spanning the canal and carrying the propellers to be tested and the apparatus required, and running on a track extending the length of the canal.

(2) A transmission dynamometer for the measurement of the power absorbed by the propeller.

(3) Means for driving the propeller through the dynamometer at speeds varying through a wide range, and for any run in constant proportion to the speed of the truck along the rails.

(4) A thrust dynamometer for measuring the thrust developed.

(5) Means for registering time, distance, and revolutions.

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Carriage or Truck.

This consists essentially of a platform about 8 by 18 feet, and carried primarily on two 10 inch steel channels spanning the canal, with two shorter I beams framed in between at each end, as shown on the general arrangement plans of Fig. 1. Between

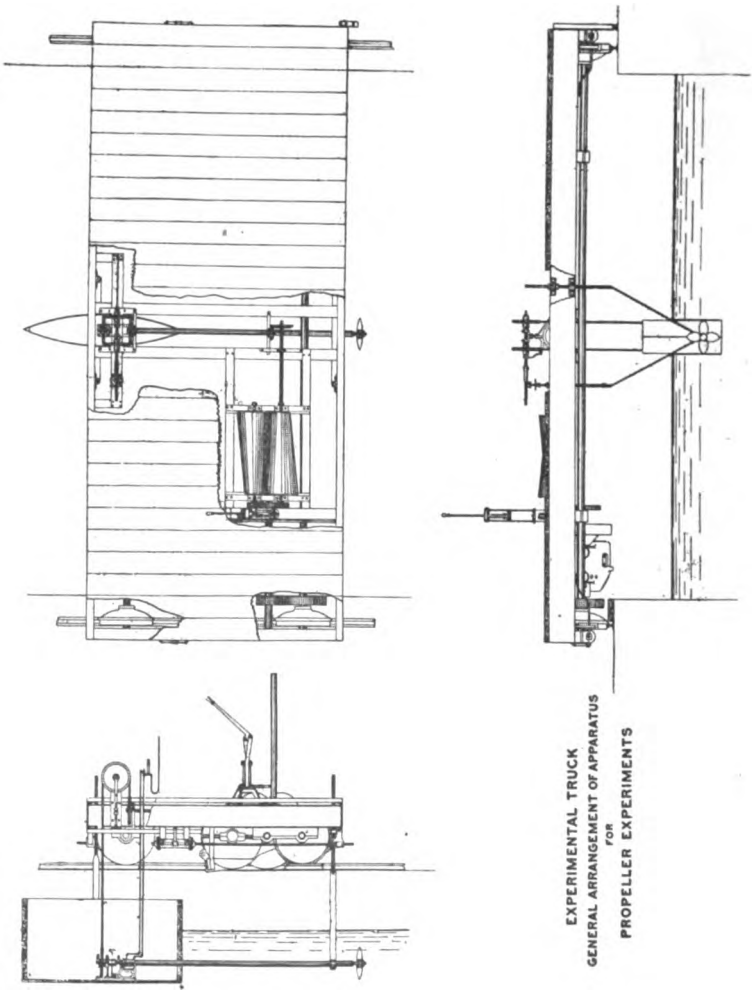

FIG. 1.

the latter are carried the wheels and motive power. The latter consists of one 15 H.P. electric motor geared down by a double

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reduction to the driving axle. The range of speeds at present contemplated is from about 100 to 800 feet per minute, or from about 1 to 8 knots. The speed of the motor is under control by means of a rheostat at the starting end and in circuit with the field coils of the generator in the power house. By means of this setting rheostat an adjustable E.M.F. can be readily provided at the motor, and thus any speed obtained within the limits provided.

For the more common range of speeds, 300 to 500 feet per minute, the distance required for acceleration is found not to exceed thirty to fifty feet.

Transmission Dynamometer.

The form adopted is that used in the experiments previously made on Cayuga Lake and elsewhere described.* This consists of a special form of rope dynamometer as shown in Fig. 2. The rope leads around the driving sheave on the after end of the propeller shaft, the two parts passing over sheaves *H* and *I*, and then around the driving sheave *G*. These sheaves are all of the same diameter, in the present case 10 inches. The sheaves *H* and *I* are mounted with ball bearings on a shaft *P Q* which is carried by a block *L M*, the latter being connected to the base by a pair of thin plates of spring steel. This is the well known Emery support or substitute for a knife edge, and for slight movements is almost perfectly frictionless, at the same time affording rigidity in the directions desired. The sheaves *H* and *I* and their shaft thus form a balanced rocking system or lever pivoted in the middle and therefore without deflection so long as the tension of the rope on the two sides is the same. When running, however, the difference between the tensions on the tight and loose sides determines a moment which tends to throw this arm down. The downward thrust is then measured either by a spring dynamometer, or by the specially designed hydraulic step connected to a mercury manometer.

A is a cylinder with plunger fitted with extra care so as to work with small leakage of oil and almost perfect absence of metallic contact. The head of the plunger rod is spherical and is connected to the rocking shaft through the socket *B* which provides a ball-bearing rest for the spherical head and thus entire absence

* Proceedings Society of Naval Architects and Marine Engineers, Vol. V, page 107.

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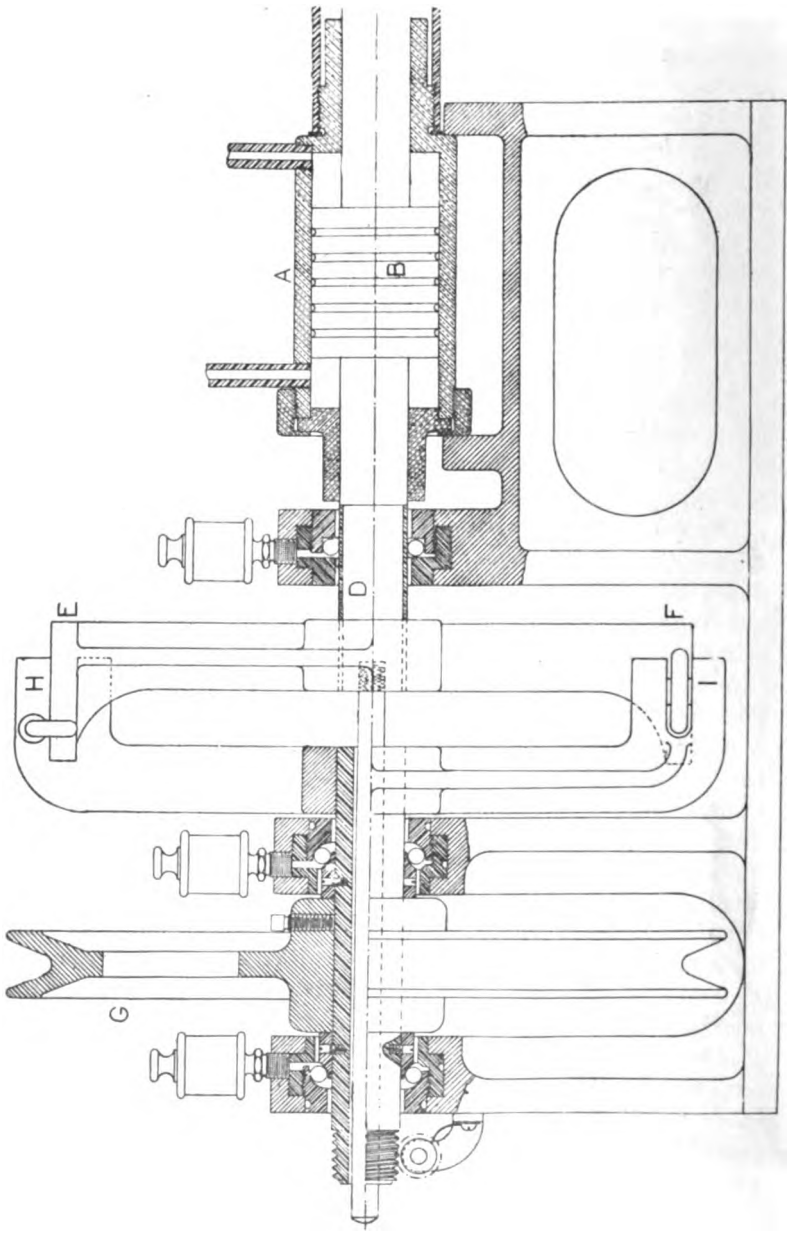

FIG. 2.

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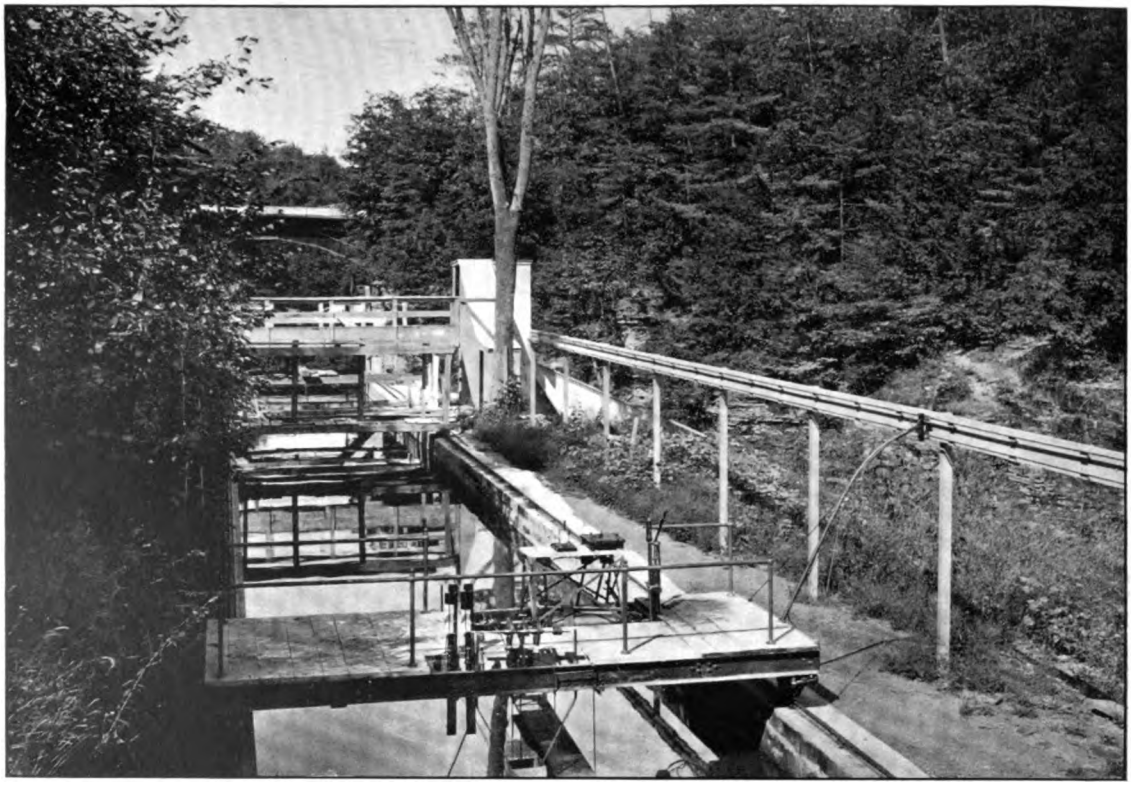

THE EXPERIMENTAL CANAL, LOOKING WEST.

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of angular constraint between the two. The base of the cylinder A is also carried on a flexible support so that any slight angular movement which may be given to it as a result of the up and down motion of B will be free from all constraint. The downward thrust of the shaft PQ is thus transmitted to the plunger and thence to the oil in the lower part of the cylinder the pressure of which is read or registered by an ordinary open mercury manometer. The movement of the shaft PQ is limited by stops to about ¼ inch on either side of the position of equilibrium. A hand pump is connected up for supplying oil to the cylinder, and this together with an overflow make it an easy matter to keep the shaft floating between the stops during the runs. In order to remove any residual frictional resistance to the longitudinal movement of the plunger in the cylinder, the plunger rod is provided with a means for rotating it on its axis either by hand when reading, or automatically, such motion being allowed by the spherical joint at the top of the rod as referred to above. By this means a very delicate measure of the forces is obtained, the reading being the height of the mercury column which may reach values of 12 to 15 inches or more. The location of the arrangement relative to the shaft PQ is adjustable so that the capacity of the dynamometer may be increased with the same range of reading by lengthening the effective arm of the plunger about the axis of the rocking couple.

The indications of the dynamometer are connected with the actual forces through a calibration by means of a prony brake placed on the propeller shaft in lieu of the propeller. For this purpose the water in the canal is drawn down leaving the brake out of water, and thus convenient for manipulation. All friction of the bearings in the dynamometers, small as it may be, is thus eliminated, and experience with this form of dynamometer shows that the indications are very delicate and accurate and the calibration constant.

Variable Speed Control.

This is effected by driving the propellers through the transmission dynamometer by a shaft connected through an Evans friction cone and appropriate gearing to the motor. The general arrangement of these features is shown in Fig. 1. By means of a single change of gears and the friction cone, a range of revolution from about 120 to 700 at a speed of about 300 feet per minute is thus provided for.

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Thrust Dynamometer.

The thrust dynamometer is shown in Fig. 3 and consists of a cylinder *A* with plunger *B* to the rod of which is coupled the

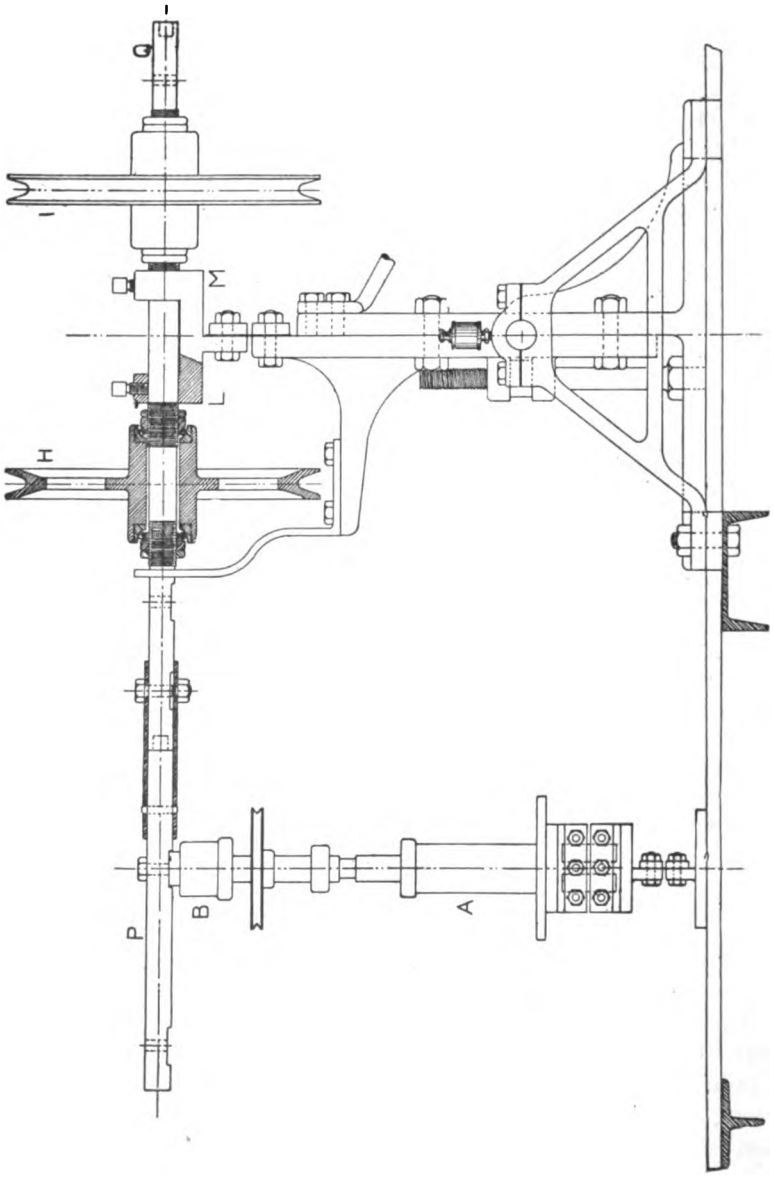

FIG. 3.

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propeller shaft *C*. The plunger rod is also continued backward as shown at *D*, and carries a pair of driving arms *E F*. The driving pulley *G* is carried on a shaft running in ball bearings as shown. The forward part of the shaft carries a second pair of arms *H I* engaging with those on the plunger rod. The connection between these pairs of arms is by means of a pair of small steel rollers carried by the arms *H I* and resting on *E F*. These rollers are carried also in ball bearings and the rollers are so adjusted that forward and backward motion of the plunger and rod is allowed by the rolling of the surfaces of one pair of arms on the rollers carried on the other pair. The torque is thus transmitted from the driving pulley to the plunger rod, with perfect freedom for the latter to move longitudinally back and forth. These various parts are carried in a small caisson or boat pointed fore and aft and hung from the truck by adjusting bolts, as shown in Fig. 1. The shaft which is about 8 feet in length is carried in a pipe to the forward support shown in the side elevation of Fig. 1. Here the pipe carries a ball bearing on which the shaft rotates and moves longitudinally as may be required. The other bearings are distributed as shown and the cylinder *A* Fig. 3 is simply supported between the two vertical faces of the base plate.

The plunger and rod with propeller shaft attached is thus free to move back and forth without constraint from its surroundings. In operation the propeller is run at a number of revolutions relative to the speed of advance which will give it a positive slip, and thus a pull forward. The cylinder forward of the plunger is filled with oil connected to an open mercury manometer, and the forward pull developed by the propeller is thus opposed by the pressure of the oil, and the manometer becomes thus a means for measuring the force as desired. The space behind the plunger is also filled with oil under pressure from a stand pipe with a small reservoir on the upper end, and at the height of the manometer. This balances the column of oil in the pipe between the manometer and the cylinder and leaves the mercury in the former free to record simply the forces developed by the propeller. A small hand pump is provided for forcing oil in forward of the plunger, as well as an overflow for allowing it to escape, so that between the two the location of the plunger may be adjusted as desired, and leakage of oil may be made up as necessary. The motion of rotation eliminates practically all frictional resistance to the longitudinal motion of the shaft, so that all of the pull developed by the propeller is transmitted to the oil, and the apparatus as a

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whole is found to provide an extraordinarily delicate and accurate measure of the forces involved.

The indications of the dynamometer are connected with the actual forces through a calibration effected by the use of a bent lever fitted with a knife-edge bearing, one arm of the lever being horizontal and the other vertical. To the former are hung known weights, while the end of the latter presses against the plunger shaft through an intermediate steel rod passed through a hole in the shaft of the driving wheel *G*. The shaft being then rotated, known weights are placed on the horizontal arm thus producing known pressures axially on the plunger shaft. These pressures are measured by the manometer in the usual manner, and in this way its indications are connected with the actual forces in play.

The automatic registration of the forces in both the power and thrust dynamometers is made by means of a special type of open end mercury manometer as already referred to above. The indications of the mercury column are registered by the use of an aluminum float carrying a slender steel rod moving in guides, and to which is attached a light pen carriage and pen. The latter is held by a very light spring against the paper, and the whole is free to rise and fall in answer to the movement of the column of mercury. In practice it is found that this form of recording device is reliable and sensitive, and that it can be depended upon to respond with certainty to the movements of the mercury column. The vertical drum carrying the paper is given motion from the driving axle so reduced as to revolve once for a complete run over the course. The indications of the manometers are thus recorded on a distance abscissa and show the history of the variation of the forces throughout the entire course of the run.

Records of Time, Distance and Revolutions.

These records are all made by a chronograph of special form and recorded on a strip of moving paper. The time signals are furnished by a clock with electric seconds break attachment. The distance marks are given by an electric contact arrangement along the rails, and the revolutions by an electric contact attachment counting every fifth revolution of the propeller shaft.

Special Purpose of the Equipment.

As already indicated the special purpose for which this apparatus has been designed and installed relates to experimental research in connection with the performance of screw propellers.

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Without developing these points in detail it will be sufficient to note that the performance of a screw propeller depends, outside of its diameter or absolute size, on the following chief features: pitch ratio, slip, area of blades. Besides these are several other secondary features such as shape of blade, distribution of thickness, etc. These various features may all vary independently and the complete investigation of the results of variation among even the chief features becomes thus a very long and serious undertaking. The present purpose is the prosecution of these investigations covering the main features as above mentioned.

There remain also many special investigations relating to propellers which may be studied by the same apparatus. One of the most important of these is that of two or more propellers on the same shaft, the special points in question being the proper distance apart axially and the proper relation between pitch and distribution of area for the best results as regards thrust developed and efficiency of performance.

There are also many questions of fundamental science which may be investigated by the same general apparatus or with slight variations or additions. The programme of possible and really important work which may and which should be done is so large that there will be no trouble in utilizing all the time and capital which can be found for the prosecution of these and allied lines of work.

One of the most striking exhibits in the Electricity Building at the Pan-American Exposition was an immense weldless field ring, destined for service in the new plant of the Niagara Falls Power Co., and exhibited by the General Electric Co., who are to supply the ten new generators of 5,500 horse-power each. This ring, which is of nickel-steel, measures 142 ½ inches outside diameter, 130 ¾ inches inside diameter, leaving the walls 5 ⅞ inches thick, while the width of face is 50 ¼ inches. The weight is about 35,000 pounds. When in place on its generator, this ring will revolve at the rate of 250 revolutions per minute, giving a peripheral velocity of 9327 feet per minute, or 106 miles per hour.

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THE COST OF RUNNING TRAINS AT HIGH SPEED.

BY JOHN G. CRAWFORD.

This article is based on the results of tests made on the Chicago, Burlington & Quincy Railroad, during July, 1900, under the direction of Mr. Max H. Wickhorst, Engineer of Tests. The writer, together with Mr. Geo. W. Ristine, Jr., at that time students of Cornell University, assisted in the tests and prepared their graduating thesis from the results. The report of the committee on "Cost of Running Trains at High Speed," presented at the recent meeting of the American Railway Master Mechanics' Association (Eng. News, June 27, 1901) included the results of these tests as furnished by Mr. F. A. Delano, Superintendent of Motive Power.

The tests consisted of five runs from Chicago, Ill., to Burlington, Ia., a distance of 206 miles. Three runs were made on fast mail train No. 15, and two on a special train of the same make-up, run at half the speed and carrying no lading. The fast mail train leaves Chicago at 9.30 p. m. and arrives at Burlington at 1.18 a. m. making an average schedule running speed of 55 miles per hour. The special train left Chicago at about 8.30 a. m. and its schedule was made out by doubling the time between the stations and at stops. The fast mail train makes two crossing stops within the city limits of Chicago and station stops at Mendota and Galesburg, 82.8 miles and 162.5 miles from Chicago, respectively. The special train was to have made only these stops, but was blocked several times.

Train No. 15 was hauled by engine No. 1590. This engine is of the Columbia type, with cylinders 18 x 26 ins., and total weight of 128,700 lbs. The special train used engine No. 1121, American type, cylinders 17 x 24 ins., and total weight 89,700 lbs. The object of using different engines was to have an engine suited to the service.

The trains consisted of the dynamometer car, two baggage cars and two mail cars. The average weight of the mail trains was 180 tons, and that of the special train 160 tons. The records taken were coal and water consumption, speed, draw-bar pull and steam pressures.

In studying the results of these tests the following items should be taken into consideration :

(1) The weather during the tests was most favorable for easy running and low cost of operation ; light winds, temperature about 70°, and rain for only 40 miles out of the 1,000 miles of running.

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(2) The special trains were required to make an average of four stops more than scheduled on account of being blocked. The mail train was required to slow down to about 15 miles per hour on new track and the special made a number of slow-downs. These additional stops and slow-downs mean additional fuel and water consumption.

(3) Engine No. 1121, which was used on the special train, is somewhat larger than would be required on a train of this character, and was in consequence underloaded.

(4) The coal burned per square foot of grate surface per hour was in the case of the fast mail train 109.1 lbs., as against 49.1 lbs. in the case of the special train. The coal used was the best grade of screened lump Illinois coal, known as Streator No. 1.

(5) If doubling the speed of a train doubles the resistance at the draw-bar, then the horse-power at the draw-bar is increased four times and the work done on the train in hauling it a given distance, together with the horse-power hours, are doubled.

RESULTS OF DYNAMOMETER TESTS OF FAST MAIL TRAIN NO. 15 AND SPECIAL TRAIN.

	Train No. 15.	Special train.
Schedule running speed, miles per hr.	54.88	27.44
Actual running speed, miles per hour	56.24	28.69
Weight of lading, tons	16.7	0.0
Total, of train, etc., tons	263.4	219.7
Excluding locomotive and tender, tons	179.8	159.85
Coal used, lbs.	12,690	6,149
Per ton-mile, lbs.	0.3342	0.1869
Per sq. ft. of grate surface, per hour	109.1	49.1
Per sq. ft. of heating surface, per hour	2.37	0.805
Average boiler pressure, lbs.	184.0	149.0
Water evaporated, lbs.	63,770	38,525
Used per ton-mile, lbs.	1.7233	1.1710
Average developed H.P., at draw bar	325.0	64.8
Developed H.P. hours, at draw-bar	1,192	464.0
Draw-bar pull, lbs.	2,164	844.0
Per ton hauled, lbs.	12.1	5.3
Steam used, draw-bar, H.P. hour, lbs.	53.3	83.0
Water evaporated per lb. of coal	5.03	6.27
Water evaporated *, per lb. of coal	6.02	7.46

*From and at 212° F.

For comparison the following table is given; the fast train being the standard:

	Train No. 15.	Special train.
Speed	100 %	51.0 %
Draw-bar pull per ton	100 %	43.9 %
Water per ton-mile	100 %	68.0 %
Coal per ton-mile	100 %	55.9 %
Horsepower at draw-bar	100 %	19.9 %
Work done at draw-bar	100 %	39.0 %
Horsepower hours at draw bar	100 %	39.0 %
Steam per draw-bar H.P. hour	100 %	156.0 %

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The results of these tests show that the draw-bar pull per ton was more than doubled by doubling the speed, and that the water consumption per ton-mile was increased only 50 per cent., while the coal consumption per ton mile was nearly doubled. The draw-bar pull per ton is computed from the average draw-bar pull, and is not corrected for grades, curves or stops.

The increase of only 50% in water consumption per ton-mile when the speed is increased from 30 to 60 miles per hour is due to the greater efficiency at the draw-bar of the engine used on the fast mail train. The engine used on the special train was underloaded and consequently less efficient. As the engine on the fast train overcomes a greater head resistance than the one on the slow train, this fact should tend to make the fast mail engine less efficient at the draw-bar.

The greater efficiency of boiler and grate in the case of the engine hauling the slow train is due to the lower rate of combustion employed.

There being only two points showing the relation of speed to coal and water consumption, one the result of tests at 30 miles per hour, the other the result of tests at 50 miles per hour, one would hardly be justified in stating a general law of the effect of speed on coal and water consumption. The tests tend to show that increasing the speed from 30 to 60 miles per hour doubles coal consumption and increases the water consumption 50%. Taking into consideration all things influencing the results, it seems more than likely that had the engine on the slow train been more nearly adapted to the service, the water consumption, and consequently the coal consumption, would have been less. Hence, a justifiable conclusion is that increasing the speed of a four or five-car train from 30 to 60 miles per hour more than doubles the coal and water consumption, probably an increase of not exceeding 120% for water and 175% for coal. The above percentages were figured from the draw-bar HP. hours, taking into consideration weights of train and assuming a water rate for the special engine as low as that for the fast mail engine, also taking account of the greater efficiency of boiler and grate in the case of the engine hauling the slow train.

NOTE :—Published by the courtesy of *Engineering News.*

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COMPOUND LOCOMOTIVES, AND THE RICHMOND LOCOMOTIVE EXHIBIT.

H. WADE HIBBARD.

The collections of Sibley College have recently been enriched by the reception of the Pan-American exhibit of the Richmond Works, American Locomotive Company, as shown in the photograph upon another page. It is a full-sized section of the Richmond Compound Locomotive. It consists of the front end of a large steel boiler, including tube sheet and smoke box, the latter with its contained steam pipes, exhaust pipe and nozzle, and arched receiver pipe or intermediate passage between high and low pressure cylinders. The high pressure cylinder and very large low pressure cylinder, with half saddles attached, are of a size which would be used on a very large locomotive, being in fact castings which might today have been in road service the same as others from the same patterns, instead of serving here a different though ultimately a no less useful purpose in the instruction of future locomotive designers, builders, and users. The "starting valves" have the valve seats sectioned out so that it may readily be seen how they operate when the locomotive is to be run non-compound or "simple" at starting, or for emergency upon a bad curve and grade or at any other temporary need of greater tractive effort to prevent stalling.

The model is placed upon a strong foundation, since its weight is about fifteen tons, and is located a few rods east of the Sibley foundry, near the edge of the gorge. It will have a platform and protection built around and over it, making it accessible for use.

Decided thanks are due to the Richmond Works for this very useful addition to the teaching equipment of Sibley College. The juniors in Steam Machinery will have it to inspect when they are becoming acquainted with compound locomotives, while of course the classes in Railway Mechanical Engineering will make the most use of the "Richmond Compound".

The compound locomotive is having a long travail in its adoption, as did the marine compound. Like many a man of decided excellence and fixed principles, it has its warm friends and still its firm enemies; and as with the man, so the compound's enemies

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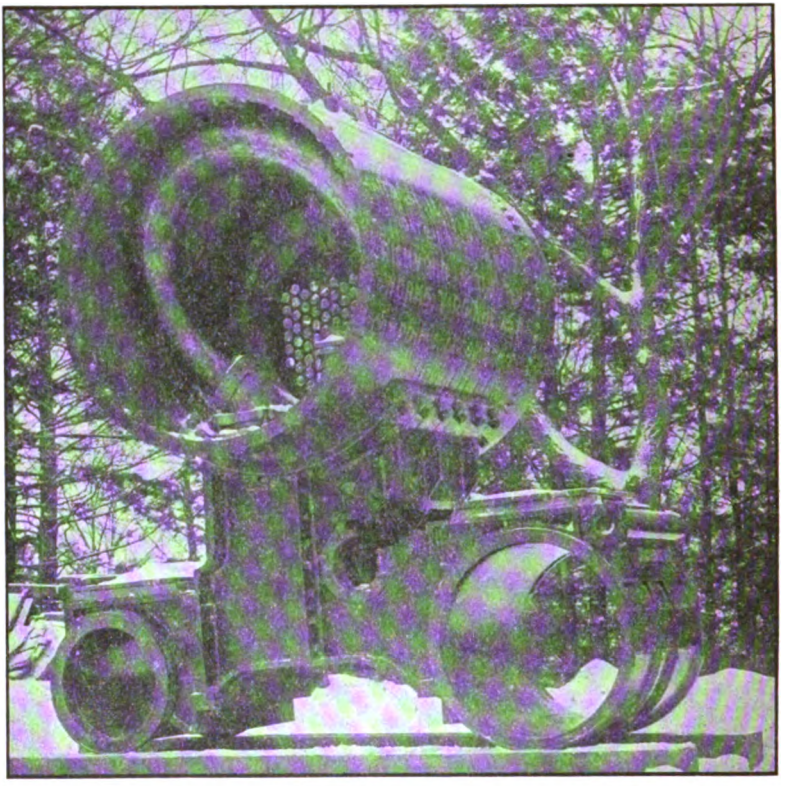

FRONT SECTION, RICHMOND COMPOUND.

are largely those who do not understand its strict principles or care to be bothered with them. Though a well-designed compound locomotive in work for which it was built will show an average of twenty per cent saving in fuel, besides many other advantages, yet if improperly designed or used it may be more wasteful than the accustomed simple engine. Its "principles" cannot be ridden over rough-shod, and cases of failure are always more widely heralded than are the begrudged successes. That is human nature, and the bad earlier designs and less successful types have been lumped in together as proving all compounds undesirable.

Locomotive engines occupy a class by themselves, being different from all other engines in their constantly widely-varying conditions of service during an hour's run,—as in adhesion, speed,

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hard-worked grade followed at once by a coast, stops, etc., with a piston speed rising from a few score feet to as high as 2,100 feet per minute and a coal consumption to over 200 pounds per square foot of grate per hour; a concentrated 1,500 horse power boiler plant and engine room on springs and wheels and a shifting steel ribbon foundation.

It is only about a decade since the first successful American compound locomotives were built. Before that time and since, the compound locomotive has, however, seen a very much larger adoption in Europe than here. During the Paris Exposition year, the writer was told at a famous continental locomotive works that they had built more compounds than simples during the preceding half decade. American railway operation is so different from European, that the compound here has had a slower progress. As the numerous difficulties appeared they were solved by real Engineers who could not be discouraged. We have found that a compound must be capable at all times of being run as a simple if desired, with all which that involves of starting valves, intercepting valves, reducing valves, separate exhaust for high pressure, etc. It must coast freely and harmlessly in spite of the compressed air in low pressure cylinder. The valves must have negative exhaust lap. Both high pressure and low pressure cylinders must do equal work at all cut offs, hence each must have its own designed steam distribution. The working cut off must be far different from the simple engine. High speed called for different designing from freight service. Cylinder ratios had to be discovered. All parts had to be made accessible American-fashion and easy to repair, and durable to stand the severe American forcing and rough, continuous usage.

During this decade of introduction of the American compound locomotive came the remarkable increase in what had been called the overloading of existing engines, and the designing of the enormously large modern freight engine. If a compound could pull a heavier load when running simple, the railway operating officer, who was ignorant of Compound Engineering and who was very properly loading all his simple locomotives to the last straw, directed to increase the train of his compounds. The result was to compel the compounds to run simple to such an extent as to reverse economy, increase repairs, and shorten life. Though later compounds were designed so as to be capable of being "overloaded" while still running compound, and thus were soon retrieving the good name of compound, their older brothers were

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still doing what they could to obscure the greatly enhanced fame of the newer designs. Modern compounds are showing a most decided saving in fuel, and this, with their other advantages, is bringing them rapidly to the front. The compound calls for and is demanded by a higher grade of engineering ability, and the increase of technically educated men in charge of railway motive power departments is giving a decided impetus to their adoption. A chance copy of the *Railroad Gazette*, picked up at hazard, tells of a week's orders for new locomotives in which there were 89 simples and 70 compounds, for eight roads.

It may be remarked in passing, that the De Glehn compound, so pre-eminently successful in European passenger service, has seen no adoption and only one little-tried experimental locomotive in America. It has two outside cylinders, and two inside cylinders which are connected to a cranked axle. Cranked axles are very un-American; but their breakages, at least in heavy modern service, as stated to the writer by many English mechanical superintendents, have been eliminated by improved design. This type permits a complete counterbalancing of the reciprocating parts, by offsetting one set with an adjacent set moving in exactly the opposite direction. This obviates the heavy counterbalance weight always found cast upon the drivers of a non-cranked-axle engine, a method of counterbalancing which is necessarily a poor compromise between excessive hammer blows upon the rails and excessive jerking and vibration upon the passengers.

The advantages of the compound locomotive may be epitomized as follows:

Twenty per cent saving in fuel, when the 38,534 American locomotives spent $90,593,965 for that item in 1900.

About the same saving in water.

Less frequent water stations to be maintained, and ability to get past a bad water district.

Longer runs between water stops and hence better time.

Reduction in non-paying weight of tenders hauled.

Ability with double expansion to utilize fully the higher steam pressures, hence reducing size and weight of boiler and cylinders.

Twenty per cent increase of power for emergency when running simple.

Greater useful per cent of adhesion in regular service because of more uniform compound torque.

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Far greater per cent of adhesion when running simple than is possible for a common simple engine, due to wire-drawn steam furnished to low pressure cylinder, more wire-drawn if starting to slip drivers, and hence self-governed from slipping.

Less fire damages along the road because of not throwing sparks, due to softer exhaust.

Less black smoke evolved, and cinders for passengers.

Easier to fire because less fuel.

An easier riding engine.

Saving in repairs to a less-forced boiler.

Saving in machinery repairs because of more even strains and less slipping of drivers.

A road engine rather than a shop engine, earning more in a year's time.

Saving in coupler rigging, car bodies, and car lading, of our 1,618,022 American cars, because of ability to start a heavy train without backing up the slack between cars and then jerking ahead.

If the four-cylindered cranked-axle type is used, perfect counterbalancing of the reciprocating parts may be obtained,—easy on rails and easy on passengers.

In conclusion, as the difficulties have been solved and the early ignorance and prejudice have become dissipated, as the enginemen and firemen and shopmen have become accustomed to the new machines, the compounds have come to be preferred by officers and men using them. When engine crews are asking to be assigned compounds, saying that they can do their work better with less trouble and make a larger coal premium, it seems as though the success of the compound locomotive were beyond discussion. It is believed that it is entering the last of the three stages through which John Stuart Mill said all reforms have to pass, viz: "ridicule, argument, and *adoption*."

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THE MINING ENGINEERS IN MEXICO.*

The American Institute of Mining Engineers made this year a trip to Mexico, to visit the Mexican mines, and obtain, first-hand, a knowledge of the mineral resources of the country. The party left New York on November 1st, and Chicago on November 2nd, in two special trains, each of eight cars. Taking the Atchison, Topeka and Santa Fe Railway, they entered Mexico at Ciudad Juarez, opposite El Paso, Texas. This was 1630 miles from Chicago, and about the same distance from the City of Mexico.

The first city visited was Chihuahua, capital of the state of that name, where La Describedora mine, yielding gold, silver and manganese, with a little iron, was visited. One of the most interesting and instructive things observable here were the large aqueduct which supplies the city with water, and the plant for purifying this water by means of alum-using filters. The filtering system appears to be a great success, and is unique in itself, as few American cities are similarly equipped. Chihuahua is a city of 35,000 inhabitants, and is some 300 years old. Some of the mines in the vicinity have been worked for about that length of time.

The next stop was at Parral, from which a side trip to Santa Barbara was made, to inspect the mines at that place. Here were seen some of the most peculiar cases of ancient and modern methods working side by side. A new concentrating works, fitted with the most modern machinery, has a compound, surface-condensing Corliss engine, while alongside it, Mexican women grind their corn by pounding it in a stone mortar. This concentrating works belongs to the Montezuma Lead Co., and has an ore capacity of 300 tons per day. Another mill, with a capacity of 400 tons, is being built. The enormous deposits of ore make their working pay, though the ore is of a very low grade. At Zacatecas, 45,000 population, another stop was made, but no mines were visited.

In the City of Mexico, the School of Engineers was first visited. This was founded nearly a century ago, and was then a school of mines. Now, however, it has 180 students, in civil, mining, and

* Abstract of a lecture delivered by Mr. William Kent before Sibley College, Dec. 13th, 1901.

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mechanical engineering. The entrance requirements include a B.A. degree. The building is palatial in furnishing and appointments, contains well-equipped laboratories and museum of mechanics, and has a splendid technical library, including all the latest works in French, German and English, as well as in Spanish. In this building a technical session was held, on November 11th and 12th, one of the papers being on "The Coal Fields of Los Esperanzas, Coahuila," where some 1200 tons per day are mined. This is sufficient to supply northern Mexico, and is an exception to the rule that Mexico is extremely poor in fuel.

At Pachuca the party visited one of the most famous silver mines in Mexico, the Santa Gertrudis, which is worked on several levels, the lowest being about 1600 feet below the surface of the ground. The water at this mine is to be cared for by an English engine, built in 1898, on the model of the old Watt Cornish pumping engines. Though it cost over $100,000 in gold, it has a capacity of only 1,750,000 gallons in 24 hours. It is a most ancient construction, having the Watt parallel motion and cataract valve gear of a century ago. The steam cylinder has a diameter of 7½ feet, with a stroke of 10 feet. So many breakdowns have occurred that the engine has been run only a few hours. A special steam capstan is fitted, to remove parts for repair. To supply this engine with steam, a battery of old-fashioned Cornish boilers is installed. As an illustration of the lack of the sense of the "eternal fitness of things" possessed by some of the men who operate these mines, may be mentioned the fact that the party saw on a side-track two enormous Scotch *marine* boilers, and on inquiring what they were doing *inland*, it was discovered that they had been ordered for use in one of the mines, but that the size of the tunnels had "quite unexpectedly" prevented their arrival at their destination, and they were on their way back to the United States.

A silver reduction works at Pachuca, known as the Hacienda de Guadelupe, makes use of the old "patio" process for the reduction of its ores. The latter are crushed, and ground fine in "Chilian" mills, then washed, and the resultant mud spread out on a flat stone pavement in layers twelve or fifteen inches thick, where it is treated with salt, copper sulphate, and mercury. It is left here for about a month, during which time it is stirred up daily by driving through it some ten or twelve mules, for two or three hours. The mules used for this purpose are usually

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worthless animals; they die from mercury poisoning in about six months. The silver amalgam having been formed, the mud is washed away and then the amalgam roasted, to separate the silver from the mercury. Fuel is so dear in most parts of Mexico that this patio process is considered better than any mechanical process which has been devised. Attempts have been made to substitute mixing machines, but have met with only indifferent success.

At Guanajuato, one of the principal mining towns in Mexico, and likewise famous for its pottery, the reduction works of the Guanajuato Consolidated Mining and Milling Co., and the mines operated by this company, were visited. Here was another example of ancient and modern methods, hand in hand. A part of the mines was lighted by electricity, but where the donkey boiler, and hoisting engine, and ore car should be, were Mexicans carrying the ore up out of the mine in sacks containing from 225 to 350 pounds each. With this burden, supported largely by means of straps or bands passed around the foreheads, the laborers climbed 80 feet up a very steep stone stairway. This region is wonderfully rich in both gold and silver, and as modern methods and machinery are making rapid advances, it is probable that before long this will become a much more important mining centre than it is at present. The city (41,000 population) is supplied with water from La Esperanza reservoir, which is formed back of one of the finest dams in Mexico. The height of the dam is about 110 feet, while it is so broad that on the top six horses may walk abreast.

At San Luis Potosi, population 40,000, elevation nearly 8,000 feet, a number of mining and manufacturing establishments were visited. In Monterey were visited the new iron and steel works of La Compania Fundidora de Fierro y Acero de Monterey. Here are a complete modern equipment of blast furnaces, Babcock and Wilcox boilers, open hearth furnaces, rail mill, foundry and machine shop, equipped with electric cranes. At an early date it is proposed to install a Bessemer plant.

The chief impression gained by the party, after an inspection of a large number of mines and reduction works, was that when modern methods of operation, together with American capital, are introduced in considerable quantity, an enormous increase is bound to occur, in the Mexican production of silver. The labor question is a knotty one. Ninety per cent. of the laborers are natives, and their "hand-to-mouth" ideas of existence are hardly

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conducive to the best results. Even where premiums of 50 per cent. are offered to men who will work *every day* for a month, only some 40 per cent. take advantage of the offer. Such is their indolence that about two tons per day represents their mining average, while a Chinaman will mine four tons, and an American about ten. The men lack initiative in a most remarkable degree, and it is only by using American foremen that anything is accomplished at all.

Mexico needs first of all the strong and just government which her present talented President, Diaz, has been executing. The introduction of American capital and industrial methods is essential to the best welfare of the country, and to its development the opening of coal mines and the building of steel works is a most important step in advance. The education of the growing youth in industrial lines, and the awakening of some ambition in the laboring classes, will go far towards putting the country on a firm commercial basis.

NOTE:—The lecturer, Mr. William Kent, an editor of the *Engineering News* of New York, and a member of several of the principal associations of engineers, has just had extraordinary opportunities to see all that interests the visitor and particularly the exploiter of the industrial resources of Mexico. Every city and town and province made the visitors its guests and entertainment of the most lavish and helpful description was provided by every official from the President of the Republic down to the most humble mine-boss or office-boy. Entertainment was provided of every sort from receptions in palaces to a bull-fight and all the ordinarily carefully guarded industrial establishments were open to the *Americanos*. The outcome of the excursion was complete confirmation of the reports already received from our representatives, official and otherwise, in that country, regarding its mineral resources, its opportunities for profitable use of capital in experienced and skilled hands and for advancement of the individual through the whole gamut of business and industrial operations. The country is rapidly being opened up by the engineers and capitalists and industrialists of the United States.

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ANNUAL REPORT OF THE CHIEF OF THE BUREAU OF STEAM ENGINEERING.

Admiral Melville reports in this document upon the condition and progress of the engineering branch of the United States navy, its personnel and material. The report is concise, clear, frank and illuminating. This Bureau has charge of all the machinery of the navy, designs the engines, the boilers and machinery of the naval fleet, writes the specifications and contracts for such as may be built by private constructors, supervises the construction, makes the tests of completed machinery and has charge of the maintenance and repair of all such machinery. It expends $3,000,000 to $4,000,000 each year mainly in repairs and preservation of the engines and boilers of the fleet. Of this work the report gives a detailed account, which is, however, not of special interest to the layman.

The new Naval Academy buildings, now under construction, are expected to cost about $7,000,000. Admiral Melville asks that of this total, about $250,000 be applied to the construction of a Laboratory for Research in the applied sciences having direct employment in engineering and marine construction. The building is to be two stories in height and 150 by 110 feet in plan, conforming in style of architecture with the buildings planned for the Academy as now in progress. It is proposed to appropriate $150,000 for its equipment. This enterprise if perfected, is another step in the direction of conforming the plan and workings of the Naval Academy to those of the great technical colleges of the world and especially in the incorporation into its curriculum of experimental work in research as well as professional instruction.

With the resources of the general government available, the comparatively small expenditures needed to make the military and naval academies professional schools of the highest class, not only, as previously, in their organization and administration, but also in their equipment and in a complete and thoroughly modern curriculum, should be readily obtained and these schools should take their rightful places as ideal, representative and model professional schools, in the extra-professional departments as well as in those which are purely vocational. In the applied sciences, particularly, they should be made perfect exemplars of the type

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which every civil as well as naval and military institution of learning should approximate as closely as means and the character of its faculty should permit. Admiral Melville is pioneering here as effectively as when within the arctic circle, and more usefully than ever did any explorer. He demands that the scientific departments of the Naval Academy, and especially the professional engineering division, be "placed upon an equality with several universities whose colleges of mechanic arts and science, in equipment far surpass the engineering outfit of the academy plant."

The staff for this laboratory is to be organized from cadets and their teachers with, perhaps, one of the officers of the old engineer corps as its director. It is not only to be used in the investigation of the technical problems of the engineer department and of the naval service but in the furtherance of the schemes of inventors where promising to be useful to the government or the public, also in testing all the appliances related to naval work, the materials and apparatus purchased by the Navy Department and in the investigation of especially important questions, such as relate to the economy of liquid fuel, the value of the steam-turbine, the form and proportions of propellers, the use of electricity and the value of electric apparatus and transmissions, the causes and prevention of corrosion of boilers, condensers and machinery, the best forms of boiler, the balancing of engines, the development of a storage battery suitable for naval use and to the use of compressed air and of gas and oil engines.

The splendid work of the laboratories of the colleges and technical and professional engineering schools of our own country and, particularly, of Germany are referred to as illustrating the promise of this enterprise.

The Chief of Bureau devotes some space to the subject of the personnel and the organization of the naval establishment, stating that the 'Personnel Bill' has thus far failed of complete and satisfactory result and asserting that it can only be expected that its purpose will be effected when the officers of the navy of every class are cordially united to carry its provisions into effect, completely and efficiently. He quotes Mr. Roosevelt, who, in the original report upon this plan, asserted "every officer on a modern war vessel has to be a fighting engineer."

The union of the engineer corps with the line of the Navy, however, has not been a complete success, so far as intended to provide the service with a body of officers equally at home above

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and below decks and capable of efficiently handling the great 'war-engine' in its every department and detail. The young officers should be given large and responsible charge of work in the engineering departments and trained as experts; otherwise that failure which was anticipated by many friends of the Navy during the discussion of the bill, as a possibility, if not a probability, must be looked for as certain.

It is stated that for every three officers taken from the engine-room for duty on deck, only one has been transferred from deck to engine-room and the vitally essential care of motive power is coming thus to be impossible; unless, indeed, a radical change of method be adopted. The "engineer's war-engine", according to Roosevelt, must have the care, each in his province, of a crew of officers and men competent, individually as well as collectively, to handle its complicated and costly machinery with efficiency and economy. Thus far the new provision of law has not insured even the maintenance of the former efficiency of the great machine. The condition is critical and the Chief of Bureau shows courage as well as discretion in his discussion of the subject.

R. H. THURSTON, in *Science*.

The Annual Report of the Bureau of Construction and Repair, of the Navy Department, has just been issued. An appendix to the report is interesting as showing in tabular form, the number and classes of vessels now in the United States Navy. In the "regular" Navy are 252 ships, aggregating a displacement of 626,935 tons, or an average of 2,488. In the "auxiliary" Navy are 55 ships, of a total of 167,757 tons, averaging 3,050. Grand total, 307 ships, 794,692 tons, average 2,589.

Of these ships, 18, of 218,092 tons, are battle-ships; 11 of 128,595 tons are armored-cruisers; 19, of 56,665 tons, are coast-defenders. This makes a total of 48 armored ships, displacing 403,352 tons, or an average of 8,403. Of the unarmored ships, 20, of 81,838 tons, are protected-cruisers; 53, of 99,329 tons, are cruisers and gunboats; and 60, of 13,254 tons, are torpedo craft, including 8 submarines. This makes the sum-total of actual war-vessels 181, displacing 597,773 tons, or an average of 3,303. The remaining 126 ships, of 196,919 tons, are colliers, supply-ships, tugs, police-boats, etc. The above figures include ships both built and building.

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Admiral Melville, the Engineer-in-Chief of the U.S. Navy, in his article in the January *Forum* on the "Military Duty of Engineering Institutions," says:

"The greatest tribute that can be paid to the work of the naval, military and engineering professions is to mention the fact that there is a high standard of integrity and honor existing among the members. Particularly can the noble words of Ruskin be applied to these three professions:

'And so with all other brave and rightly-trained men. Their work is first, their fee second—very important, but still second. And with some people, just as certainly, the fee is first and the work second. And this is no small distinction. It is the whole distinction in a man; distinction between life and death in him, between Heaven and Hell for him. You cannot serve two masters; you must serve one or the other. So then you have it in brief term: work first, you are God's servant; fee first, you are the fiend's'."

* * * * * * *

"With each succeeding year, the curricula of the military and naval academies have more closely approached those of the best schools of technology. At the present time, therefore, it can be confidently asserted that there are scores of institutions that could carry on, at least in part, the work that is now being done at Annapolis and West Point. Paradoxical as it may be, there are two scientific institutions in this country that give a better course in naval architecture than the one given at the naval academy.* There are at least four colleges that possess as complete and extended a course in marine engineering as the one established at Annapolis. There are a dozen institutions whose courses in electricity far surpass that given either that at Annapolis or West Point. As for the courses of instruction in modern languages, physics, chemistry and applied mechanics, there are a score of colleges that devote as much time to instruction, and that possess laboratories as complete as those at the government schools."

* Presumably the Sibley College of Cornell University and the Massachusetts Institute of Technology.—EDITOR.

Lehigh University is erecting a stone laboratory, 90 x 43 feet, to be used in connection with the steam engineering work of the course in mechanical engineering. Next fall the university will offer a new and extended course in electro-metallurgy—the first of its kind, it is believed, to be established in this country.—*American Machinist.*

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Department Notes.

Owing to the congestion at present existing (and from all signs likely to continue) in the shops of Sibley College, the course has been shortened from a total of 1,100 hours to 900, the remaining 200 being now elective. This abreviation affects all the shops except the Wood-shop. Foundry and Blacksmith are each reduced from 200 to 150 hours, and Machine-shop from 400 to 300. This does not mean that the Sibley College Course has been shortened by that amount, for an equivalent has been added to the required electives in the Senior year. The shop requirements are now identical for all courses in Sibley College, instead of showing, as before, 1030 hours in Electrical, Marine and Railway Engineering and Naval Architecture, as compared with 1,100 in Mechanical Engineering.

A seventh edition of Dr. Thurston's "Manual of Steam-Boilers" has just appeared, in an enlarged and revised form. It is published by John Wiley & Sons, New York. The preface explains the scope of the enlargement and revision, and closes by stating that "On the whole it has been sought, and it is believed with a fair degree of success, to place before the user of this volume the latest and best information available and in such condensed form as will make the book at once the most complete, the most convenient and the most economical possible work of reference and manual for designer, builder, engineer and engineman."

Sibley College has made the usual annual contract for lubricating oils for shops, laboratories and lighting station, obtaining oils of fine quality and of considerable value at the usual discount, "100 per cent. off the list-price."

Here is a sample call in the department of Manual Training :—

"I am looking for a man to take charge of the manual training department in this school and I write to you to find out whether your department has any special course for training those who wish to take up that sort of work and also, in case there is, to ask whether you could direct me to any man who will fill the bill. We have a two-year course in shop work and mechanical drawing followed by an additional optional year of

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mechanical drawing; and we would want a man, not merely who is well equipped for taking charge of the shop and drawing rooms in this work, but a man of general culture and who in the matter of personality would meet the somewhat critical demands of a community such as this is—some one who could command the respect and confidence of the boys."

SUPERPOSED-CURRENT DISTRIBUTION,—A patent granted Nov. 5, 1901 to Dr. Frederick Bedell describes a system of electrical distribution employing currents of different character, and particularly a constant potential system employing both alternating and direct currents. The inventor has discovered that if an alternating current be superposed on a direct current, the line loss will no longer be the square of the sum of the two currents, but the sum of their squares, multiplied by the resistance. This involves a large copper economy in distribution systems, or, conversely, a higher efficiency of transmission. For example, if on a direct-current system an alternating-current system is superposed, by doubling the copper, four times as many lamps as before can be supplied; or in supplying current over a common conductor to devices such as two incandescent lamps, with one ampere of direct and one ampere of alternating current, respectively, the energy received by the respective receiving devices is the same, while the energy lost in the conductor is only one-half the corresponding amounts of energy in case both devices received like currents. Several applications of the system are shown. In the simplest form, an alternator is connected at one side to one leg of a direct-current circuit, and from the other collector ring a conductor is run to form a third conductor in the combined system. Lamps are connected between the two direct-current conductors, and also between one of the direct-current and the alternating-current conductor. In a more symmetrical application, there are two direct current generators and two alternating-current generators in opposite sides of a closed circuit. If we assume the form of the circuit to be rectangular, then there will be a main of the working circuit leading from each angle of the closed circuit. In order to secure a maximum of economy, any one translating device in the circuit should be supplied with current of one character—that is, either direct or alternating current. This implies a balance of line losses, and means are described whereby this condition of balance may be maintained. —*Electrical World and Engineer.*

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Personals.

'92. Charles W. Gibbon, M.E., (M.M.E., '93,) John H. Godfrey, M.E., '95, and Robert L. Gordon, M.E., '95, are with the Pressed Steel Car Company, of Allegheny, Pa.

'93. John R. Whittemore, M.M.E., is with the Erie City Iron Works, of Erie, Pa.

'94. William B. Gregory, M.E., holds the chair in Experimental Engineering, at Tulane University, New Orleans, La.

Chester P. Wilson, (M.E. '95, M.M.E. '96) is now the responsible engineer and superintendent of the lines of the Camps Bay Tramway Co., at Cape Town, South Africa. The lines are in part in operation and the remainder gradually coming into use. He writes Dr. Thurston of anticipation of a Christmas with fresh strawberries with the turkey and plum-pudding. Business matters are resuming shape in South Africa and the great mines gradually resuming their output. The Rand mines are increasing their work at the rate of fifty stamps a week and the diamond mines are now in possession of powder-works of their own. He is living in the "Upper Gardens, with Table Mountain on one side and the Devil's peak and the Lion's Head in front and behind." On the completion of the work now under construction, he expects a change of scene, though not of employers.

'96. George H. Stickney, E.E., is in the testing department of the General Electric Company, at Lynn, Mass.

'98. Clay Belsley, M.E., has an office as Consulting Engineer, in Peoria, Ills.

'98. William F. Devendorf, E.E., is installing instruments for the Bell Telephone Company, of Buffalo, N. Y.

'00. Charles S. Gladden, M.E., Business Manager of the 1899–1900 SIBLEY JOURNAL, is with J. G. White & Co., consulting engineers, of New York City.

'00. Frank Martin, E.E., was married on Thanksgiving Day, 1901, to Miss Daisy Beach, of Groton, N. Y. Mr. Martin is with the Matthieson Alkali Co., of Saltville, Va.

'00. Virginius D. Moody, E E., is in the calculating department of the General Electric Co., of Schenectady.

'01. Ernest S. Holcombe, E.E., has recently joined the staff of the J. C. Lorring Arc Light Co., of Philadelphia.

'01. Frederick W. Bailey, M.E., is in the draughting room of the Russell Engine Co., of Massillon, Ohio.

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'01. Maurice Parke McKay, E.E., and Henry W. Eells, are in the testing department of General Electric Co., at Schenectady. Their work at present consists in testing the largest machines put out by that company, among which are now the first of the ten big Niagara Power Co. generators, of 5500 horse-power each.

'01. Isaac H. Francis, M.E., is in the office of Henry Adams, consulting engineer, in Philadelphia.

Ex. '01. Gilbert S. Lang, was for a time connected with the Fall Brook Railway Company, with headquarters at Corning, N. Y. He is now with the General Electric Co., at Schenectady.

M. M. Green, (M.E., '94) contributed to the *Beet-Sugar Gazette* for April, 1901, an important article on Lime-Kilns for Beet-Sugar Factories. It details the results of an inspection-tour in Europe made mainly for the purpose of ascertaining what had been accomplished in the improvement of the mechanism of beet-sugar manufacture on that side of the Atlantic.

The article gives an interesting, concise and clear account of the chemical principles involved in the operation of the lime-kiln for this line of production and shows how its direct and its by-products are liberated and what are the directions in which approximation to thorough efficiency are sought. The lime-kiln in this case is treated as a regenerative furnace of which the stone and the coke are the gas-producing elements and the lime the ash. The former enter cold and are "regenerated" by the outpassing hot gases, while the cold air enters in contact with the lime and is thus heated before combustion. The art of efficient operation, where the stone and the coke have a fixed composition dependent upon the locality, as is usually the fact, is that of burning the coke with minimum volume of cold air, that of securing complete "regeneration" and that of insuring, as accessory to the latter requisite, proper distribution of the air and gas currents, and, as a minor point probably, protection against loss of radiated heat by suitable lining and insulation.

Automatic machinery for charging the kiln, and for drawing the lime and ash, should be used, and every precaution taken to secure uniformity and accuracy of action throughout. These methods may increase production above 25 per cent over the less effective method. By proper construction and operation, a gain of ten times the increased cost of construction of the kilns has been made practicable, even with what are to-day regarded by many as creditable existing kilns in some of our largest plants.

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BOOK REVIEW.

PRACTICAL MARINE ENGINEERING *for Marine Engineers and Students, with Aids for Applicants for Marine Engineers' Licenses.* WILLIAM F. DURAND, Ph.D., Professor of Marine Engineering, and Principal of the School of Marine Construction, Sibley College, Cornell University. Published by *Marine Engineering*, Inc., 309 Broadway, New York, 1901. Price $5.00. Pp. xiv + 706. 368 illustrations.

As stated in the preface: "The purpose of the author in the preparation of this work has been to provide help for the operative or practical marine engineer, either for the man who has already entered the profession, but who may wish to perfect himself more fully in many branches of the subject, or for the applicant for the lowest round of the ladder, or for the young man whose attention is first turning to this field, and who may wish some simple and fairly complete presentation of the subject from the practical standpoint."

The first chapter deals with the *Principal Materials of Engineering Construction*, including a short discussion of the usual methods of testing these materials. Chapter II treats of *Fuels*, both solid and liquid, with considerations of such subjects as transportation and stowage, corrosion, spontaneous combustion, danger of explosion (of liquid fuels), and the cost of liquid fuel as compared with coal. In the third chapter appears a comprehensive discussion of marine *Boilers*, with descriptions of the more important types of fire-tube and water-tube boilers, an extended consideration of the various forms of riveted joints, a treatment of materials and construction, boiler-mountings and fire-room fittings, and draft; finally, a section on "Boiler Design in Accordance with the Rules of the U. S. Board of Supervising Inspectors of Steam Vessels."

Chapter IV deals with *Marine Engines*, treating quite extensively of the various modern types of engines and arrangements of parts; giving a fully-illustrated description of the principal elements employed; noticing special forms of engines, such as those used on the western rivers, and the steam turbine; and ending with a detailed discussion of engine fittings and special gear, and the question of piping and valves. In chapter V we find the subject of marine *Auxiliaries* comprehensively treated. From the point of view of the practical marine engineer, chapter VI is one of the most important in the book. In it are considered *Operation, Management and Repair*. The innumerable emergencies and troubles attending the operation of marine machinery are discussed, and quick remedies for many of them are suggested. The question of overhauling and repairs is accorded very considerable attention. The chapter ends with a consideration of the spare parts to be carried, and the "laying-up" of marine machinery.

Valves and Valve Gears call for extended notice in chapter VII, concluding with directions for valve-setting. In chapter VIII is found a discussion of *Steam Engine Indicators and Indicator Cards*. Chapter IX deals with *Special Topics and Problems*, such as heat and the formation of steam, coal consumption, strength of boilers, feed-water heating, clearance, amount of condensing-water, and the computation of the weights of machinery parts. Chapter X is devoted to *Propulsion and Powering*, including a discussion of the screw-propeller. Chapter XI deals with *Refrigeration*, and chapter XII with *Electricity on Shipboard*.

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Part II, *Computations for Engineers*, is an elementary discussion of the main principles of arithmetic and geometry as applied to the subjects under consideration, together with such parts of the applied sciences of physics and mechanics as bear on the matters at hand. At the end is a table of the properties of saturated steam.

The book, as a whole, is unusually complete for one dealing with so wide and extensive a subject. In every department, the key note seems to have been—simplicity. Written in an easy style, it is such as to be easily read by men lacking the advantages of any extensive education; and this, without any loss of exact methods, or of accuracy of detail.

The Indicator Handbook, Part II. The Indicator Diagram: Its Analysis and Calculation. By CHAS. N. PICKWORTH. Published by D. Van Nostrand Co., 23 Murray St., New York. 1901. Price $1,50.

This little book of 132 pp. takes up its subject in much detail, going into the causes of various peculiarities in indicator diagrams, and illustrating scores of typical cards, from all types of engines, and a large number of forms of cycles. The third chapter, treating of diagram analysis, is a particularly valuable one, as it is here that the indicator diagrams shows its greatest worth. Cards from a great variety of engines are discussed from this standpoint. The next chapter takes up diagrams from compound engines, including the methods of obtaining "combined" cards. Gas and oil engine cards call for a separate chapter, and are systematically and thoroughly discussed. Cards from air-compressors and pumps are next considered; while the last chapter deals with diagram calculations, developing the method of subdivision, as well as that by the use of planimeters, a number of the standard forms of which are illustrated and described. The 148 figures add largely to the value of the work.

L'Electricité à l'Exposition de 1900. Published with the co-operation and under the technical direction of Mm. E. Hospitalier, editor-in-chief of the *Electrical Industry*, and J. A. Montpellier, editor-in-chief of the *Electrician*, with the assistance of engineers and industrial electricians. Vve. Ch. Dunod, publisher, Paris, 1901. Price of the entire collection, which comprises some 15 numbers, 50 francs.

The ninth number (seventh in order of appearance): "Telephony and Telegraphy," second section: "Telegraphy", by L. Montillot, inspector of the mail and telegraph, has just appeared. It forms 246 large pages (9 x 12), with 143 figures.

La Mécanique à l'Exposition de 1900. Published under the patronage and the technical direction of a committee of editors, under the presidency of M. Haton de la Goupillière, inspector general of the mines. Vve. Ch. Dunod, publisher. Paris, 1901. The eighth number (ninth in order of appearance): Apparatus for Hoisting and Carrying, by M. M. R. Masse, 108 large (8¾ x 12½) pages, with 136 figures. Price of the entire collection, consisting of some 20 numbers; 60 francs.

This takes up in considerable detail various forms of traveling cranes, both the overhead span type and the locomotive jib crane; capstans and winches for hoisting purposes; traveling sidewalks, platforms and stairs; aerial cable tramways; conveying belts; ore-conveyors, and other forms of elevator apparatus; and a number of minor items comprised under the general head shown in the title. A number of examples of each type of apparatus is shown, which the numerous illustrations aid in describing with considerable completeness.

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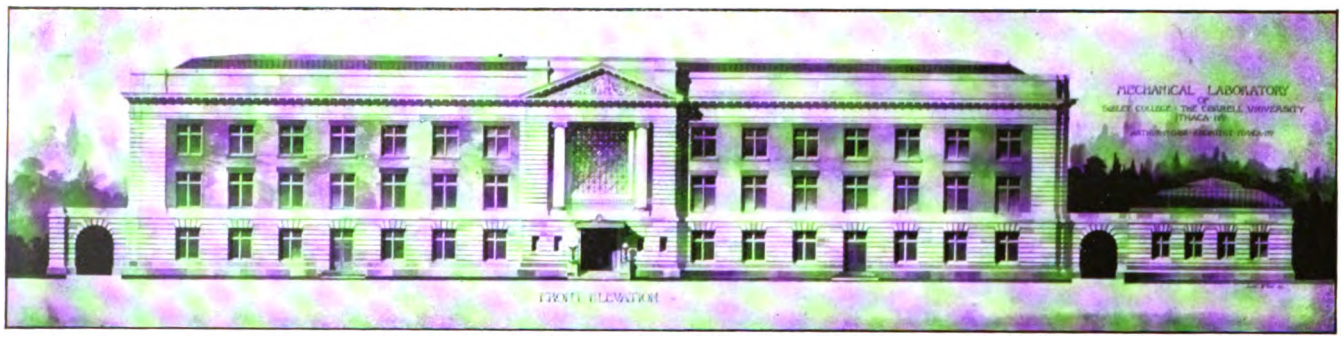

STUDY FOR A MECHANICAL LABORATORY.

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THE SIBLEY JOURNAL OF ENGINEERING.

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IN CORNELL UNIVERSITY.

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislature of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

ENGINEERING IN THE CHEMICAL INDUSTRIES.

R. H. THURSTON.

In most of those great industries which produce chemical products, the success of the business depends, as an essential point, upon the work of the engineer. If he has not properly designed and constructed the mechanical details, the apparatus and machinery of the works, failure is quite as certain as where, the works properly built, they are not properly operated by the superintending engineer. The extent to which the success of the business depends upon the skill, talent, experience and judgment of the engineer depends, in some degree, upon the extent to which the establishment is operated as a great machine composed of a large aggregation of machinery, on the one hand, and, on the other, as merely a piece of simple apparatus, a retort or other, magnified and set to perform a great task. In the latter case, there is small opportunity, as a rule, for the engineer.

In the majority of large chemical works, however, there are two essential elements in the organization. The engineer and the chemist, who may perhaps be called the "chemist engineer" and the "engineer chemist", or, as perhaps more usually denominated, the "chemical engineer" and the "industrial

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chemist." The former of the last two titles infers a man of special talent and preparation for a position which requires, at once, extensive professional knowledge and experience as an engineer and sufficient familiarity with the fundamental principles of general chemistry and of the special chemical work in which he is interested to enable him to adapt his designs and his constructions to the particular purpose in hand and, at the same time, to understand so clearly every essential operation of the works in which he may be engaged that his every effort and his work shall be perfectly fitted to the common purpose of the chemist and the engineer and to the ultimate purposes of the business. The latter of these two officers is presumed to be a man whose special talent and professional training are those of the chemist proposing to give his working life to applied chemistry and industrial enterprises within his professional purview and who should be sufficiently familiar with the apparatus and machinery of the business to be able to precisely adapt his work, when occasion arises, to the available mechanism and methods of the establishment.

The first of these professional experts is primarily an engineer and secondarily a chemist; his vocation is engineering, his avocation, in a sense, chemistry as finding application in his work. The second is primarily a chemist, secondarily a mechanic; his vocation is that of the chemist, his avocation may be engineering as applied in his line of work. The one should be professionally an engineer and an expert in chemical engineering, and especially familiar with the branch of industrial chemistry in which he finds occupation; the other is presumed to be professionally a chemist and an expert in those chemical departments of production in which he proposes to engage, and also sufficiently familiar with the professional work of his colleague to be able to work into his hands with mutual advantage and for the advantage of the business as a whole.

The history of the chemical industries is rich in illustrations of the successes which have come of the proper selection and correct professional assignment of such men, as well as of the sad failures which have followed the attempt of the responsible authorities to conduct the business without the one or the other, or to entrust the work of either to the other. The engineer has his place and is wise to leave the work of the chemist in the hands of the professionally trained and expert chemist; and the chemist who has attempted to perform the work properly assignable to the engi-

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neer has often illustrated the most magnificent of failures. Working together, each in his proper field, highest success is assured.

Some of the greatest successes yet recorded for graduate mechanical engineers have been reported in these departments of production. Not only in the establishments of the classes above mentioned but also in a number of others, notably the cement industry, many of our alumni are doing admirable work. These successes admirably illustrate the principle which, however often forgotten, invariably asserts itself in the end, that experts, not amateurs, are wanted in business. The engineer must be trained in the school of the engineer, in college and out of college; the man who desires to become valuable as a chemist must be taught first of all by the expert chemist; the engineer taught by a chemist would be simply an amateur and the chemist taught by the engineer would be possibly even less reliable; but the accomplished and experienced engineer, coming from a good school of engineering and experienced in his craft, with a supplementary training in the special line of work chosen, or the well-instructed chemist, the pupil of able chemists of age and experience and reputation, with supplementary training in the art within which his science finds application, are both sure of the highest success that the great industries can offer those equally well-equipped men.

The lesson cannot be too well impressed upon the novice in engineering. Let him first get his fundamental culture in good schools, then his professional training in the best professional school; next his special accomplishments from the most experienced and capable teachers, and only natural defects of character or lack of ability can prevent his ultimate success. In the case under consideration, could the young mechanical engineer secure a good education, a thorough professional training and, if proposing to enter the work of mechanical engineering in the great chemical industries, an adequate special course of instruction from the chemist practically familiar with the industry in view, his would prove a model preparation.

On the other hand: could the young chemist, proposing to enter a line of work connected with a great chemical industry in which the processes involve more or less of mechanical engineering, supplement his professional work with at least the fundamentals of the theory of mechanical engineering and secure some practical acquaintance with its practical side, he would find

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himself much better prepared to reinforce the best work of the engineer. For the young engineer, the case is precisely that of the man who would become the expert adviser of the inventor, who supplements his engineering training and practice by a course in patent law, as have, in fact many Cornell alumni; but, in all cases, the successful engineer is the product of the engineering school and of expert instruction, while the lawyer is the output of the law school and its eminent faculty. The courses here suggested do not infringe the axiomatic principle now obtaining in all professions, that the engineer must be taught by engineers, the chemist by chemists, and the lawyer or the medical man in the schools of law and of medicine.

There has recently appeared in the University Register a paragraph calling attention to the opportunities presented for supplementing the work of the regular course in mechanical engineering by special work in chemistry for those desiring to enter the manufacturing industries in this department. It reads thus:—

"Excellent opportunities are opening in increasing numbers for men trained as mechanical engineers and familiar with the processes and methods of industrial chemistry. Students interested in this specialty may profitably supplement the work of the course in mechanical engineering by the various courses in analytical and industrial chemistry, as specified under Chemistry in the Academic Department. The elective time of the regular course in mechanical engineering may be given to these subjects and in special cases, permission may be obtained to substitute work in applied chemistry for a certain part of the work of the regular course."

As illustrating the nature of the career sometimes open to young men of the right spirit and ability, who have acquired the necessary knowledge and technical training, we may take the case of a graduate of Sibley College of 1891, who went into this department of industry and, active and ambitious, continually sought and secured opportunities. In the record reported, under the rules, as candidate for admission to one of the great technical associations, we find the following summary, in substance:—

——— ——— ———, as member, (b. 1866.) (M.E., Cornell Univ., 1891.) 1891 to 1896 Engr. of Tests, The S. P. Co., improving methods and reducing costs of operation and production; 1896 to 1897 Engr. of new works, and in charge of engineering during construction; 1897 to 1900 Supervising Engr.

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and Gen. Engr. for S. & Co.; summer 1900 to date in private practice, general engineering. His backers and nominators are leading members of the society.

While large salaries cannot be expected by young men without a record behind them of considerable extent and great excellence, it is the fact that even alumni of Sibley College, though necessarily, as a rule, amongst the youth of the profession, are here and there securing important appointments. One is at the head of several manufacturing organizations, aggregating four or five millions of dollars in capital and paying remarkable dividends, thanks to the genius of this young mechanical engineer; another stands at the head of one of the greatest manufacturing establishments in the field of chemical industry in this country, with large profit to himself as well as to his stockholders. In many large works, of various kinds, these men are coming forward in larger and larger numbers, making a success wherever combining the right spirit with the right training and experience and with the always essential talent for getting on with all sorts and conditions of men. One, some time since, refused an offer of $8,000 to go to a foreign country; another accepted a somewhat smaller salary, as a beginning, to go to a still more remote but more attractive field; another made his contract for a period of years, at a salary "larger than that of a college president," and others, in all directions, are here and there making themselves worth a large compensation and securing the equivalent in value received; for, after all, the exchange of service for compensation is usually made on such a basis that the payment on the part of the employer will afford a good profit. The period of gaining practical knowledge and experience in one's vocation is one of large compensation, though not always in dollars; the period of financial returns is apt to come after years of perhaps impatient waiting and hoping; but it is certain to come, if the man can make his services profitable to his employers.

In recent years there has come to be a considerable demand for men of both the classes here referred to and it has been found that, as Mr. Edison once said to the Director of Sibley College, the man trained as an engineer and also familiar with applied chemistry is one of the most difficult of all to find when wanted. The "wizard" has himself frequently called for Sibley College men to aid him in this field and has had in his employ some of the ablest alumni of the college, usually in electro-metallurgical work. In compliance with this demand it has been for some years customary to arrange

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for deviation from the regular courses and for provision of special work in chemistry much as had previously been usual in the schools of marine, railway and electrical engineering. This provision was first made about 1890 with the cordial co-operation of the Department of Chemistry and now it is formally announced as a substitute course in the University Register.

Still later, it has been proposed that students in chemistry should be given some work in the elementary branches of mechanical engineering as introductory to entrance upon the work of the Industrial Chemist. Opportunity and space permitting, it seems probable that this may be done.

In order to ascertain to what extent there may be expected to be a demand for these two classes of graduates, the Director recently addressed to officers of two classes of these typical industrial establishments, a request for an opinion, selecting as the one type the "soda-ash" industry, and, as an example of the other type, "alkali works." In the one we have a very considerable quantity of machinery, in the other practically none other than simple apparatus for vibrating the cells of the electrolytic process and that required in barrelling the product. It was thought that the one would illustrate the establishments in which there is much, in the other those in which there is very little machinery.

The cement industry is one which has been most remarkable for its rapid growth in the United States during recent years and one in which large opportunities have been found and utilized by young men of this class among the alumni of the College and the University. Among the first to enter the field were graduates of Sibley College, and the business is coming rapidly to be largely directed by them. One of the best authorities on the matter in question, as familiar with the business on both its scientific and practical sides, is Professor Carpenter, who had something to do with a number of the latest and largest installations in recent years. In reply to a series of interrogatories, this authority writes thus:

"There is an excellent demand for mechanical engineers in these industries and the pay is good for competent men. Those are preferred for this work who have some practical familiarity with the chemist's side of the business, and such men are doubtless able to do better engineering work in connection with the manufacture than those who have no chemical training.

"As all these works require chemists in order to secure correct

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mixtures and proportions, there must also be demand for such men, and it is probable that the chemical work would be better done if the chemist had a thorough knowledge of engineering work; although I doubt if good results would be produced if the chemist had merely a smattering of mechanical engineering.

"The duties of the engineer and chemist would, in large works, be distinct. The mechanical engineer would attend to the design, construction and operation of the works, while the chemist would see that the proper proportions and mixtures were supplied. They would need to coöperate to produce satisfactory products.

"The probable line of promotion of the engineer would be that of superintendent and general manager; as his training and work would especially fit him for such a position. The chemist would similarly receive promotion, under usual conditions, in his line of work."

The general manager and chief engineer of one of the greatest organizations in its field, the Solvay Process Co., of Syracuse, is a Sibley College man who, prepared for college at fifteen, determined first to learn the business of marine construction. Then, after four years of business, he came to Cornell to secure inspiration from one who is, he considers, the greatest among American mechanics, Professor John E. Sweet, and to gain much technical and scientific knowledge; for he was a most industrious worker and thoroughly in earnest. Too impatient to get back into business, he could not wait to take his diploma but left college with the class of '78 and went into the then youthful beet-sugar industry, as Mechanical Engineer and Assistant Superintendent of a new "plant." Thence he went to the Solvay Process Co., as draughtsman, became, successively, head draughtsman, chief engineer, general manager and chief engineer, and a director in the company. There he still remains.

His views of the needs and opportunities of the young Mechanical Engineer and of the demands for good chemists having some notion of mechanics are given by him thus:—

"There is certainly a demand for Mechanical Engineers having a more thorough knowledge of chemistry than has been obtained in the usual college course. Twenty years ago, the Mechanical Engineer was expected to have a general scientific education, which included what was then known of chemistry, electricity, metallurgy, and part of the Civil Engineering course; now we find college graduates specializing in various sub-divisions of the

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profession. It seems to me, however, that the foundation of all is a thorough knowledge of Mechanical Engineering.

"So much machinery now enters into our everyday life that the man who can understand and manage machinery has a good foundation, and, whatever super-structure he may build upon it, if the foundation is good, success is assured.

"It is much easier to teach a good Mechanical Engineer enough electricity, or enough chemistry, to enable him to fill a responsible post, than it is to teach a Chemist or an Electrician mechanical engineering. Any instruction in mechanical engineering which the Chemist can get will be to his advantage in industrial chemistry. The best man would be one who had graduated in both departments; but, as the habits of thought and of work are so different in the two classes of men, it may be very difficult to prevent one or the other science from predominating, and you may turn out a man under those conditions who is neither a good Mechanical Engineer nor a good Chemist. The heads of industrial enterprises—the men who rise to the top of industrial chemical works—are the Mechanical Engineers. This is especially so in the class of industries with which I am familiar, where machinery is the predominating factor.

"I will answer the questions by numbers as follows:—

(1) There is a demand, in Industrial Chemical Works, for the Chemical Engineer—that is, a Mechanical Engineer who will perfect himself in chemistry to thoroughly understand the theory and to be able to apply the results obtained by the Chemist.

(2) The Industrial Chemist is in demand in more purely chemical works, and in proportion to his knowledge of mechanical engineering.

(3) To the Chemical Engineer would be assigned the practical management of departments of the chemical industrial works; he would have the supervision, first, of one operation in a department until he grew able to manage all; paying particular attention to the machinery, but having knowledge enough of chemistry to understand the particular operation and to correct troubles from the results of analyses made by laboratories. To the Industrial Chemist would be assigned experimental work to be undertaken on a large scale, after laboratory experimenting had shown the way, or the supervision of such delicate chemical operation on materials of high cost as would require especial care and comparatively small amounts of machinery. The two types of man employed in the same department would naturally divide

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on these lines, and their work overlapping as circumstances and the particular process involved might require more chemistry and less machinery, or *vice versa*

(4) The line of promotion of these men would depend almost entirely on their personal characteristics and the process in which they were employed. As the development of machinery, however, has as great an effect on cost as the improvements in chemistry, and as the development of machinery means more control of the men employed, it is probable that the Chemical Engineer would become Manager.

"As Vice-President and Consulting Engineer I am connected with the By-Product Coke Oven Industry, and the utilization of these by-products is a wide field which is growing very rapidly. My experience with the appointment of men to manage the various plants of these coke ovens, has confirmed what I have previously said with reference to the Chemical Engineer.

"I believe you will be working on right lines if you begin by developing the Chemical Engineer from the Mechanical Engineer, giving him as much of the modern languages (French and German) and of Chemistry as he has time for and developing his mechanical engineering education along the lines of Steam Engineering, Hydraulic Engineering and Physical Sciences rather than the training which would fit him for the manufacture of machine-tools or other purely mechanical manufactures.

The General Manager, who was also the builder, of the great Electrolytic Alkali Works at Niagara Falls, and who has just increased their magnitude and output to three times their original measures, answers in substance as follows :—

(1) "There certainly is a demand for just such men ; but I should say that it would be here better to have a man primarily a Mechanical and Electrical Engineer. The modern electrolytic process is comparatively simple and merely a repetition of known reactions, day after day. There is no chance of revolutionizing the process by radical chemical changes. The well-equipped Mechanical and Electrical Engineer can always see chances of improving the efficiency of the Electrolytic process. That is to say : the chemical side of the business is standard and based on well-known principles. In our work, for instance, we have to deal with the decomposition of salt. A salt solution has a certain electrochemical equivalent or, in other words, it has been demonstrated that it requires a certain potential to break up the solution of salt into its component parts of sodium and chlorine. This decompo-

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sition can be effected in many ways; as either by the Castner process employing the mercurial cathode, or by some of the diaphragm processes, or by the Acher process which decomposes fused salt and deposits the resultant sodium on melted lead, as a cathode; but the efficiency of any of these methods depends almost entirely upon the mechanical efficiency of the appliances. For instance, in our process we could readily decompose the brine, but unless our cell is properly oscillated and the caustic and brine compartments thoroughly isolated in the proper mechanical manner and the iron grid or cathode maintained electrically clean, the cell will not work at its best efficiency. No matter how beautiful the process may be from the Electro-Chemist's standpoint, it is worthless commercially unless it can make money, and the money-making product of an electrical cell depends upon its current efficiency. The different processes should run at a high efficiency; but they can only run at a high efficiency if the mechanical parts of the cell are perfect. Thus we are able to maintain an efficiency of 90 % and this efficiency enables us to return profit to our stockholders; but if our cells should run, say, at 60 %, it would be another story. While the chemical principles would be the same, the difference in efficiency lies solely in the mechanical features.

(2) There is certainly a demand for the Chemist, but he is not expected to take part in the mechanical work. He is employed to make tests of solutions and products.

(3) The Mechanical Engineer with a knowledge of chemistry, would be given every possible chance to work out his ideas for increasing the efficiency of the process. The Chemist would report, from day to day, on the condition of the solutions in process of manufacture and on the finished product.

(4) The Mechanical Engineer with a knowledge of chemistry, would be promoted as far and as fast as his ability would warrant. If he was of the right kind he would become manager of the works.

(5) Undoubtedly the Mechanical Engineer, with some knowledge of chemistry, would be an efficient manager; for the actual electrolytic decomposition, in a factory such as ours, is only one department in the work. The manager of the plant should be familiar with electrical transforming machinery; he should also be enough of a machinist to know that his repair-shop is being run efficiently; he must see that the mechanical features of the cells are working to their best advantage and he must be familiar

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with hydraulics, in order that he may keep up his complicated brine circulation. He must be familiar with the best methods of conveying gases, such as chlorine, and must so arrange that such gases are mechanically transferred to the absorbing chambers and properly mixed, not only chemically but mechanically, with the absorbing element. He must arrange to clear the absorbing chambers with the greatest dispatch and with the least labor and not only attend to the manufacture of the packages in which the product is shipped, but also to see that the product goes into these packages with the least cost to the Company. He must be familiar with furnace-building, so that the caustic evaporating pots may be set to do the most work with the least applied heat. Moreover, if his plant is up-to-date, he must be familiar with mechanical stokers and the conveying machinery for taking out the ashes. He must know how to unload a car of salt for the least possible cost and get that salt into solution. These are only a few points that the manager of works must be up on."

The preparatory career of this very successful "Chemical Engineer" included a course, terminating with A.B., in a famous eastern college, supplemented by graduate work in Sibley College and the Cornell University laboratories. Subsequently, three years of travel abroad, in which period every important establishment in any industrial field which was encountered was studied, gave something of a finish to the education and professional training of the man. He then became connected with the enterprise in which he has distinguished himself, built the works and made handsome dividends for his stockholders, who now give him entire freedom in extension and further improvement. It perhaps should be noted that the case illustrates the influence of heredity; his father was one of the greatest mechanics and patent lawyers that this country has produced. His forefathers included two Masters of the Mint in the time of William the Conquerer and numerous relatives of the present and earlier generations are known to have similar proclivities. But he states "I believe that it was the knowledge derived at Sibley College which fitted me for my work".

The General Superintendent of the large Alkali Works of the Mathieson Company at Saltville, Va., a Sibley College graduate, replies:—

(1) "I unhesitatingly answer yes. Less than ten days ago I was in the office of a friend who is largely interested in chemical manufactures and who was anxious to know if I could recom-

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mend to him a competent engineer to take charge of his plant. He said they were then simply feeling their way and losing time and money, not having a man competent to take charge of their work.

(2) "To this question the answer is the same: Yes!

(3) "In general, the manufacture of heavy chemicals, especially alkali and bleaching powder, is largely a problem for the Mechanical Engineer. It is nine-tenths, at least, an engineering, rather than a chemical, problem. The manufacture of chemicals by the Ammonia Soda Process involves large questions of power, including boilers and engines, pumping machinery, piping, machinery for handling raw materials and finished product, furnace construction and design, as well as milling and finishing machinery, all of which are properly solved by the engineer.

"The preparation and working up of the raw materials, the utilization of by-products, the careful supervision of all tests and reactions, having to do with the quantity and quality of output, as well as the economical consumption of raw material and the prevention of unnecessary waste, are problems for the Chemist.

(4) "The Mechanical (Chemical) Engineer having so large a connection with the construction and operative departments would naturally gravitate towards the head of the operating department. The Industrial Chemist's field would lead in the direction of the Superintendent of Processes or the taking charge of chemical work in certain departments.

(5) "Unquestionably, the Mechanical (Chemical) Engineer would be efficient as manager, from his broad experience, gained through intimate contact with problems of design and operation, as well as his great familiarity with methods of handling men.

"The Industrial Chemist has usually, from lack of engineering training, little practical knowledge as to the best methods of carrying out his ideas, some of which are often very good, others the reverse. I think the idea of training 'Chemical Engineers' a good one.

"The General Manager in the largest alkali works in this country is an engineer. The man who built the works is one of the leading engineers in the country. The men in charge of the Niagara branch of our works are engineers by profession. The General Manager of the Detroit plant of the Solvay Process Co., is an engineer.

"Work done at Cornell, in turning out Chemical Engineers,

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should be done as graduate work, after a full course leading to the degree of Mechanical Engineer. *Turn out first-class Mechanical Engineers first;* afterwards, let them take up such chemical work as will fit them for the *special branch* of chemical industry they desire to go into. They will find that they will learn more chemistry after they get into practical work than they could ever acquire at college."

In the report of the Director of Sibley College to the Board of Trustees, discussing this subject, June, 1901, we find the following:—

"*Chemical Engineering* has come to be a very important requirement of the industrial system of the United States and of the state of New York as well. Our industries in this department have not only enormously broadened and diversified during recent years; but they have changed, like all other industries, in the direction of a more perfect system, and a more thoroughly organized administration. More than all, a vastly more scientific method and basis distinguishes every industry of this class, to-day, from that of the earlier generations. The evolution has been precisely that which has occurred in all other leading vocations and industries. As the profession of medicine has been evolved out empiricism, as that of engineering has more completely than ever before based its greatest achievements upon a sound and systematic scientific method; so these industries have come to rest upon a foundation of applied science and of scientific research directed to a definite purpose and a specific end.

"Until very recently, working chemists and chemical engineers expert in the mechanical apparatus and processes of these industries, were very rare: they are less common to-day, by far, than is desirable. Among the first to go into this branch of engineering were Sibley College and Cornell University men. Their successors and aids have been very largely drawn from the ranks of our alumni; while almost all chemical manufactures have found places for our alumni in later days.

"The extent of these industries is not often realized by even the most well-informed of our public men.

"We are now importing about $50,000,000 *per annum* in products of the chemical manufactures and this should mean the development of our own industries in these directions, to this extent and more, at an early date. In ten years, we have reduced the importation of caustic soda by the evolution of our own manufacture, as by the Solvay process and kindred methods, from

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about $1,500,000 to about $150,000 and there is no reason in nature why we should not do as well in many other directions. Soda ash has been similarly reduced from an importation of $3,500,000, nearly, to a little more than $500,000 and glass, imported in 1890 to the value of $7,500,000, has been brought down to $4,000,000 very nearly.

"Meantime, our exports show the real extent and importance of the movement in development of our chemical industries, most of which are largely dependent for their prosperity upon successful mechanical engineering. We exported, in 1876, a trifle over $100,000,000 in chemical products; in 1890 we sent abroad about $175,000,000 and in 1900 the export valuation was reported officially as about $265,000,000, in round numbers. The growth during a quarter of a century has thus been about 60 per cent. The coke industry has quadrupled in twenty years rising from a production of $6,631,000 in 1880, to above $25,000,000. The chemists are making it a paying industry by showing how to secure and utilize the by-products. Between 1500 and 2000 millions of dollars are invested in the chemical industries, apart from the gas manufactures. It is stated that over $2,000,000 are invested in the new electrolytic manufactures. About 5000 chemists are now engaged in this department of industry and the number of positions which need, for their proper working, good Mechanical Engineers, well-educated and well-trained as specialists in this field, should be even greater. Both are more and more needed and the situation is becoming constantly more critical. In Germany, about 200 chemists are constantly employed in research and it is in this direction mainly that our requirements exceed largely the supply of strong men in both professions. More men and better training are the constant demand of these industries upon the college of technology.

"A School of the Mechanical Engineering of Chemical Manufactures is one of the important divisions of our work which has long been in contemplation, but which has been held in abeyance while other, and for the time more pressing, enterprises were promoted or perfected. Such an institution includes in its scheme an immense variety of interests having for their common bond of union much such a system of applied science as distinguishes in its special field the various branches of Electrical Engineering. It is a field of work in which the engineer is compelled to supply machinery and apparatus and to organize establishments and to operate them in the application to industrial

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purposes of the principles and methods of chemical analysis and synthesis. Strictly speaking, all metallurgical operations and the mechanical engineering of mining are either properly assigned to this division of our work or are closely related thereto.

"The metallurgical and mining divisions were many years ago made a part of the scheme of Sibley College and Mr. Sibley still has, in his collections of plans of that early date, those of the then-proposed constructions for the mining and metallurgical school. The recent introduction of electric energy in any desirable quantity and of any needed tension, whether for simple transmission of energy from point to point, for the lighting of a town or mill, or for reduction of ores or production of alloys or of chemical products of any sort, has greatly extended the range of the operations of chemical engineering and the organization of a branch of the mechanical engineering college and curriculum to meet this now important need has come to be well worth while.

"The so-called 'Chemical Engineer', like the 'Electrical Engineer', requires primarily that efficient and complete training in the principles of the sciences and the arts which underlie the work of the designer and constructor of machinery, that which constitutes the curriculum of the School of Mechanical Engineering, and in such form and of such range as will enable him, after some comparatively short practical experience, to take useful part in the manufactures of machinery. Supplementing this work in the engineering school, the engineer should have instruction in the design, construction and operation of those special kinds of machinery and apparatus which find application in this class of manufactures and the chemical industries generally and some elementary but exact instruction regarding the planning and organization of establishment. He must then go into the business selected and acquire a knowledge of its details.

"The 'Chemical Engineer' must be primarily an engineer but yet a good chemist; although, in every important establishment, he will find himself reinforced by an expert specialist chemist.

"In the works, he will be called upon to join hands with the superintendent, the workman, the business manager and the chemist in tracing out the sources of the various losses which reduce the output, lessen the economy of the business and lower the efficiency of the establishment considered as a machine. If he can assist effectively in detecting these losses, in measuring their amount and in ascertaining their cause, the remedy will

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usually be found, in whole or in part, practicable, and the business will profit by his intelligence and learning ; if he fail, the business will suffer.

"It should be easy for the friends of these industries and those of state industrial education to strike hands with the authorities of Cornell University and Sibley College and secure such additions, moderate as they are required to be, to the already extensive and directly applicable equipment and staff of the College as may be needed in the establishment of the School of Chemical Engineering on a sound and safe basis and on an ample scale."

"A former pupil writes the Director of Sibley College :

'I want to bring to your attention the value of a better and more thorough course in chemistry in the early education of the Mechanical Engineer. The Phillipines, Alaska, the Greater and Lesser Antilles, New Brunswick, Nova Scotia and in fact the entire Dominion of Canada, to say nothing of South America and Africa, open an unbounded field for first class mechanical engineers who are well versed in chemistry and mining.'

"A considerable number of Sibley College men are, in fact, already doing fine work abroad." One has the direction of the Capetown system of railways; others are employed in the great diamond mines at Kimberly, the Manager of which is an American who formerly had a son at Cornell, now assistant superintendent of the mines. Several are in London offices of important enterprises and others are engaged in the works of American companies in Europe. A few have done good work in South America and in Australia and others are going or preparing to go to the West Indian and the Phillipine colonies of the United States. Many have found occupation in Mexico and natives educated at Cornell are in many instances creditably representing their own countries and Cornell University in the development of their own home industries."

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THE CARNEGIE TECHNICAL SCHOOL.

Plans for one of the largest and most complete schools of technology in the world were adopted by the board of trustees of the Carnegie Institute (Pittsburg) on October 9th, 1901. The committee having the work in charge had called to its assistance a number of the leading educators, on technical lines, in the United States. The advisory board thus formed consisted of

Dr. ROBERT H. THURSTON, Director of Sibley College.

Professor J. B. JOHNSON, Dean of the Engineering Department, University of Wisconsin.

Professor THOMAS GRAY, Rose Polytechnic Institute, Terre Haute, Ind.

Professor V. C. ALDERSON, Acting-president of the Armour Institute, Chicago.

It is desired to place the new school near the Carnegie Institute, as the library of the latter is rich in technical and other valuable works, which need not be duplicated in the library of the new institution. It was the intention of the donor that the city should furnish the land upon which the school of technology should be built, but it seems to be the opinion of the advisory board that, as Mr. Carnegie proposes not only to build and equip, but fully to endow it, it would be better to purchase the land, and thus keep it forever free from political influences.

As to the scope of the new school, it was considered whether it should follow in the footsteps of the best of the American schools of technology, uniting the best features of one school with the best of another, or whether it should venture upon entirely new fields, to push outward the borders of human knowledge. The American, German, English, French and Swiss schools have been studied in this connection.

Professor Johnson's proposed scheme includes three colleges of university grade, giving courses of four years, with high school preparation, and conferring degrees at graduation. These colleges are of Science, of Engineering, and of Commerce. Schools of Manual Training, Domestic Science, Industrial Design, and Commerce are recommended, each with a three year's course, with grammar school preparation. Each such school would be of high school grade, granting diplomas at graduation. An Artisan Day School, with a course of three years, would include

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instruction in subjects of essential importance in the practice of the various trades. Provision is also made for a night school, for the benefit of day workers.

Dr. Alderson's recommendations comprise (1) a Department of Engineering, including Mechanical, Electrical, Civil, Chemical, and Electro-Chemical Engineering, Foundry Practice, and Metallurgy; (2) a Department of Secondary Education, including work preparatory to the College of Engineering; and secondary technical education, offering courses in machine tool work, stationary engineering, elementary mechanical and electrical engineering, foundry practice, surveying, machine design, drafting, glass-making, blacksmithing, pattern-making and brass-making. Departments of Library Economy, of Art, of Evening Instruction, and of Domestic Arts and Sciences are also included.

Dr. Gray recommends that the institute offer a course of instruction covering the whole nine years of study; that it be divided into two distinct schools, a secondary, and a higher college or professional school. He advises that the course of instruction in the former include all the subjects commonly given in the best high schools, with the possible exception of Latin and Greek, and in addition the subjects more commonly given in business schools or colleges. Provision should also be made for practical instruction, either manual or otherwise, bearing upon the particular branch of industry which the student intends to enter. Dr. Gray recommends that the upper school "provide a college education for men of the rank of shop foremen, superintendents, etc. In this course, which should be of two years' duration, instruction can be given in such subjects as the design of structures and machinery, the properties of materials and machines, the design and management of power stations, telegraphy, and a host of other subjects, the understanding being that these subjects be treated in such a manner that *practical* information shall be the object rather than fundamental mathematical principles."

Dr. Thurston's report is an exhaustive one, covering every phase of technical education. He asks if it be practicable to carry into effect the ambition of every technical educator, "the Technical University on the lines of which Ezra Cornell would have approved, where any man could secure instruction in any study, in such departments as are capable of being utilized practically in the sequel of life. It is obvious that could such an institution be founded, and thus the noble example be furnished in full perfection, and a standard thus provided by which to

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measure, the establishment of this complete and perfect model would, very probably, advance the cause of useful education of the people, for the life and work of the people for many years. It is possible that the opportunity is here and now presented, and that, lost, it may not recur again."

The general scheme laid out by Dr. Thurston is as follows:

A college of mechanical engineering and the mechanic arts, with eight different departments of the former.

A college of civil engineering, with six departments.

A college of architecture, with three departments.

A college of mines and metallurgy, with two departments.

A college of agriculture, with six departments.

A college of applied chemistry, with four departments.

A college of physics, with two departments.

A college of fine arts, with three departments.

A business college, with four departments.

A college of navigation and marine transportation, with two departments.

A college of mathematics, with two departments.

A college of politics and economics, with four departments.

A college of languages and literature, with four departments.

A college of philosophical science and ethics.

A college of biology.

A preparatory college, with standard curriculum.

"This scheme appears an ambitious one, but it so appears simply because we are in the very inception of educational work, and few persons have the slightest idea of the need or the opportunity for promoting the highest interests of the Nation through a thoroughly systematized education.

"The first step considered advisable in preparing to supply Pittsburg and its environs with an institution of high efficiency for technical instruction should be to make a plan of that final educational structure which is taken to represent the limit toward which progress is expected to advance. The actual construction of the scheme should be commenced with the most essential elements; the less immediately and imperatively needed parts should be arranged for later.

"The method of organization would be that which best insures the management of the whole of the great scheme and of each of its subdivisions by men expert each in his own field, whether that of director of the technical university, principal of one of its schools, or professor or instructor, or workman in shop, drawing-

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room or laboratory. Such an organization of a staff of experts being provided, the administration will be certain to work smoothly and efficiently, without special attention to detail on the part of the trustees. Their largest problem will be the matter of securing the endowment and its income from deterioration in later years and consequent impediment or interruption of the enterprise."

In the above, we have quoted largely from an address by Mr. J. A. Bradshear, delivered before the American Association for the Advancement of Science, last August, and published by *Science*, Sept. 13, 1901. Mr. Bradshear is one of the original committee from the Carnegie Institute.

The mid-winter edition of the Cornell University Register, just published, gives the first official and precise census for the current year. The figures are the following :—Trustees, 39; teachers, 387; students, graduate department, 183; graduate students in undergraduate departments, 185; academic students, 817; law school, 197; medical college, 415; college of agriculture, 86; veterinary college, 51; college of forestry, 38; college of architecture, 50; college of civil engineering, 212; Sibley college (mechanical, including railway, electrical, marine, etc.), 784. The total of all classes and courses is 2,792 in the regular lists and about 500 in the summer schools. Of the total, 1,679 come from New York state, the remainder from every state in the Union and from all parts of America and of the British Empire, from China, Japan, Russia, Switzerland, Austria, Turkey, and Korea.

Of the 784 students in the undergraduate courses of Sibley College, 62 are graduate students; there are also 14 candidates for the Master's degree and 2 graduate students not candidates for a degree. There are 4 candidates for Ph.D. taking their major work in M E. and one D.Sc., making a total for 1901–2 of 805 students in the college in all classes and courses.

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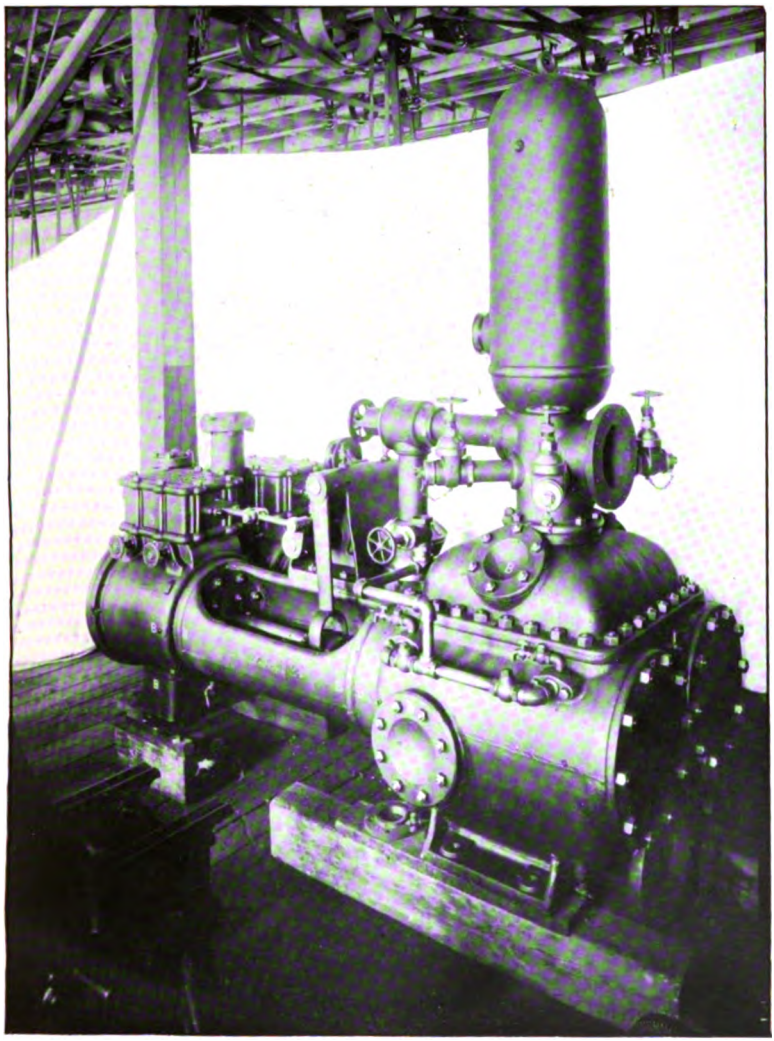

DUPLEX UNDERWRITERS STEAM PUMP.

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SIBLEY COLLEGE STEAM PUMPS.

A part of the equipment of Sibley College which has attracted considerable attention is a Duplex Underwriters Steam Pump, bearing the name of "Deane of Holyoke." This pump, which was erected in the machine shop about three years ago, was originally intended for experimental purposes, and for occasional use, should such be found necessary; but up to date it has never been connected to a source of water, and has never been tested in any way. It is situated near the west end of the machine shop, where it was erected.

At the present time another pump of almost the identical features of the first, is being constructed and assembled in the shop. In both cases, the castings were all shipped to Sibley College, free of charge, by the manufacturer. In the case of the first of the two, the steam cylinders were bored before being shipped, but all the castings for the second pump, and all other castings for the first, were shipped in the rough, and all the machine work was done here.

The dimensions of the two pumps being identical, a description of one will suffice for both. Each of the two steam cylinders of each pump has a diameter of 18.5 inches; pump plungers, 10.25 inches; with a common stroke of 12 inches. The capacity is rated at 1,000 gallons per minute, which is stated to be the equivalent of four good 1⅛ inch smooth-nozzle streams. Reduced to gallons per day, the capacity figures out at 1,440,000, or sufficient for a town of 8,000 inhabitants. At full speed, the number of double strokes per minute is about 70. The suction valves are 36, and the delivery valves 24 in number. All are the same size, 3.5 inches diameter; but while the lift of the former is ¼ inch, that of the latter is $\frac{5}{16}$ inch. Piston rods and valve rods (for the steam end) are of bronze, in accordance with a requirement of the Underwriters' Association. This metal being immune from rusting, it is always ready for fire duty, even after long periods of idleness. The total floor space required per pump is 8 feet 7.5 inches by 4 feet 2 inches.

Owing to the inaccessibility of the completed pump, surrounded as it is by lathes, planers, and drill-presses, it was never photographed until a few days ago. We reproduce the photograph obtained at that time, as well as a section taken from the drawings of the new pump.

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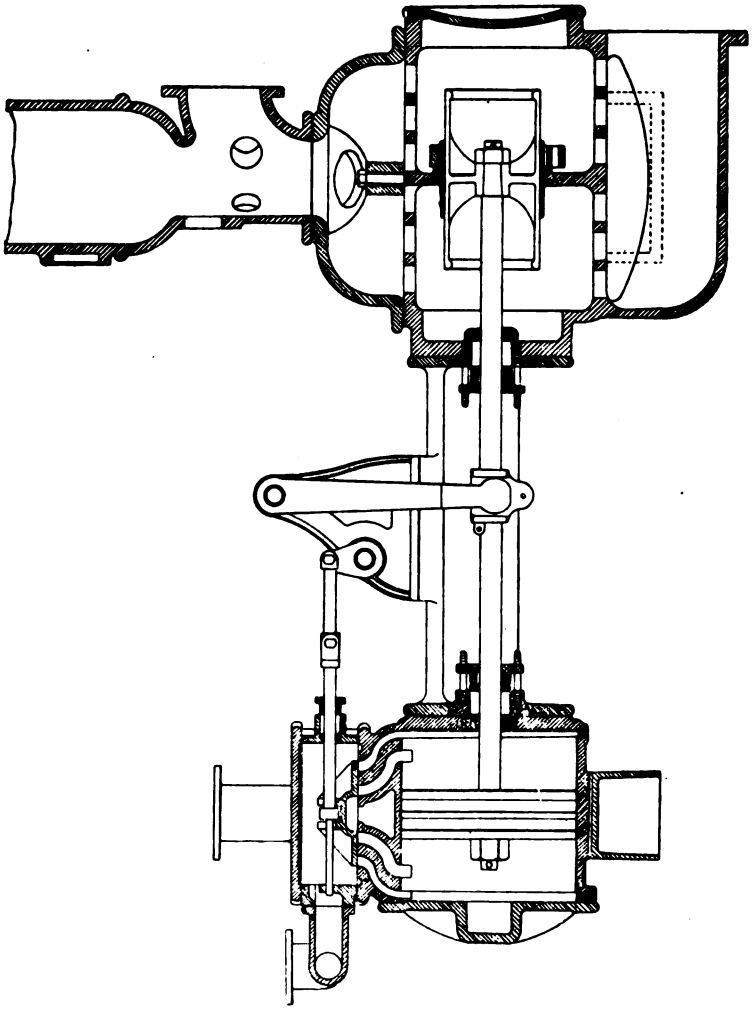

SECTION OF UNDERWRITER PUMP.

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THE COMMERCIAL SIDE OF ENGINEERING.*

CHAS. KIRCHHOFF.

It is perhaps only natural that every one who has watched significant processes of development and who has been personally influenced by them should have an exaggerated idea of their importance, and that his view point is materially shifted. Let me acknowledge that 20 years ago during a visit to a plant I was deeply interested in some modification of a familiar process, some shop kink or some special feature of detail, There was little concern in such questions as the source of raw materials and their cost, the character and the peculiarities of the product, and its destination, the system of handling not alone the materials but also the men from the manager down to the water-boy.

I am willing to admit that *now* when I look over a manufacturing plant,—and manufacturing is now engineering—the technical details have shrunken into comparative insignificance, and, frankly, the commercial side seems more important.

The reproach is often made that engineers, being too much absorbed in the technical matters and neglectful of administrative and business features are not qualified to fill the highest posts. Only last year that idea was voiced by a leading man in the iron industry when he told a class of boys at a manual training school that few of the captains of industry are college bred men. Yet that same man prides himself that he studied engineering in his spare moments. Yet the first vice-president of the same corporation is a graduate of Lehigh and two members of the Executive Board are engineers by training. I do not want to go into the matter statistically, but it is a fact that of the older men now at the head of affairs, few even had a chance at the advantages of a professional engineering education, because there were very few technical colleges 30 years ago. In the days when I was a mining student in Germany, there were five men born in the United States studying in Freiberg, Clausthal, Berlin, Paris and London to one who was learning at the two Schools of Mines then existing in this country. In those days, too, the undertaking to study abroad meant more than it does now, and then there were probably not one hundred Americans in the world who were taking a mining course.

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* Lecture delivered before Sibley College, January 17, 1902.

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What many of our self made captains of industry mean although they do not know how to express it, is that few engineers have thus far become men of affairs; in other words, that the supreme power does not rest in their hands.

It is a fact, that the feeling exists that the training and work of the engineer impairs his capacity to become a leader and the responsibe chief of large industrial undertakings. I am convinced that the next few decades when the many rise to maturity who have entered the ranks of engineering during the last 15 years, will do much to dispel this notion. So far as administrative ability, the handling of men, the management, is concerned, the proof is pretty thoroughly furnished now, but so far as the commercial side of engineering undertakings comes up as a factor in determining the choice of leadership, there are still well-founded doubts.

It seems to me certain, however, that with properly directed effort the opportunities to reach the highest rank in the industrial army are very much improved by a professional foundation, just as a purely commercial career is strengthened by a liberal education.

Young engineers when they enter upon their career must be impressed *above all* with the fact that *the one aim* of all effort must be to affect favorably the balance sheet of the undertaking. Aside from the supreme consideration of safety and occasionally the question of artistic taste, everything which the engineer does, *has* and *ought properly to have* an ulterior *commercial* end. Of course there lies beyond that the broader achievement that all well directed engineering work increases the well being of humanity, but he will best serve that greater cause who aims to produce the best commercial results through good engineering.

The work of the engineer may be divided into two classes, that of the erection of permanent structures, private or public, and that of producing articles for consumption or use. In the former the commercial side is less conspicuous, while it is the dominating factor in manufacturing in all its branches to which I desire to refer more particuiarly.

The positions of power, responsibility and trust are those which embrace not alone the production or the partly technical side, but also the commercial and financial side. In many of the great industrial plants on the continent of Europe there is a dual executive management, there being a technical and a commercial director. Usually, of course, one of them, being a man of

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greater force of character, practically controls the whole institution, but I must confess that I encountered much keener reciprocal interest and appreciation there than here in this country, or in England. I have more frequently found the commercial director closely posted as to manufacturing methods and the technical manager exceedingly alive to what might be termed business questions.

There are a good many reasons why the business management of a concern should apparently be of far greater importance than the engineering end to the average stockholder and member of a board of directors. The course of the markets justify or condemn very quickly purchases of raw material made, or sales of product effected. The engineering end may be laboriously chipping off costs. Few laymen recognize that every saving due to technical improvements is not for the day, but for all time. Few of those who hold the purse will recognize that in the long run such improvements mean enormous amounts and that they may cast into the shade the impressive results of a timely purchase of raw material, or a clever sale of product. The latter, however, will win abundant approval, when the former achievement passes almost unnoticed. There may be much injust in this, to the engineer, but the latter will do well to recognize the situation and deal with it accordingly.

As a spectator for many years, I have noted brilliant examples of the combining in one person of the clear headed, far sighted man of affairs and the progressive and well balanced engineer, and it is this type of man who, in coming years, will more and more come to the front as the great captain of industry. To reach that end, however, the trained engineer must familiarize himself and keep in touch with current developments in the financial world, and must be and remain a close student of the great economic questions of the day.

Let me say, on the other hand, that those in charge of the commercial department of our manufacturing industries often place their own interests and those confided to them at a serious disadvantage by their inability or unwillingness to appreciate the effect of technical progress.

It seems almost impossible at times to convince business men that, other things being equal, the cost of production of standard articles of manufacture is steadily and irresistibly declining and that ultimately prices must follow suit.

Some years since I had occasion to go over a series of figures

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relating to the cost of production of certain branches in iron and steel manufacture and in the metal trade. Thus at a very large pig iron plant in the south, the cost, expressed at 100 in 1889, had dropped to 63.4 in 1898, the production per day having risen from 100 to 167.7. On the coke consumption 8.8 per cent. had been cut off, while the labor cost had been nearly cut in two. A famous Eastern furnace had brought down cost from 100 in 1890 to 65.8 in 1898, the labor being reduced from 100 to 61.1. A third series of records, from the Pittsburg district, showed a reduction of coke consumption from 100 in 1889 to 86 in 1897, while the labor cost per unit of product had fallen from 100 to 46 in the same time. Taking 100 as the base in 1891, the cost of producing Bessemer ingots at a Pennsylvania steel plant fell to 64.4 in 1898, while the cost of conversion of pig iron to Bessemer ingots, exclusive of raw materials, at a great Pittsburg works, declined from 100 in 1887 to 52 in 1897. In the rolling of wire rods the production per 24 hours was 3¼ times larger at one works, per mill, in 1898, than it was in 1888, and the cost was cut down from 100 to 63.6. Similar results are found in nearly every branch of mining and of metallurgy. Nearly the whole of the saving in fuel and a very large share in the reduction of cost of labor is due to mechanical and metallurgical improvements. They may well be claimed by the engineer, and yet they are not as striking as the apparent opportunities of the commercial management. They may represent, for instance, in the manufactvre of pig iron, a saving in 10 years of $2 or $3, while prices in that time may have fluctuated up and down quadruple that sum, so that in one year a clever salesman in a boom period may add to profits the whole sum represented by a decade of engineering work.

There is a feeling among professional men that business ability means merely a trader's trickery, highly developed; that success is obtained by keeping well within the boundaries which define the allowable and the dangerous, from a legal point of view. No more serious mistake could be made. The conduct of any industrial undertaking, large or small, depends for its success upon close study not alone of prevailing conditions, but upon the correct diagnosis of tendencies, modified or thwarted possibly by local influences. The great captains of industry are the men not only of foresight, but who have the ability, the courage and the imagination to shape affairs with reference often to a distant future. They are men of thought and of action, men who are

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more than mere traders and, let me add, more than mere designing or operating engineers.

There is no country in which ability of this higher type is more needed, more liberally rewarded, too, than in our own. In our career as an industrial nation very serious mistakes have been made again and again, to which must be partly attributed both our extraordinary rushes of prosperity, our booms, and those distressing periods of depression which rob every active man, from the laborer to the great captain of industry, of years of his life, measured by the fruits of effort. It is our reliance upon the better training of the rising generations that gives birth to the hope that the future will witness a less meteoric but safer progress.

You are to enter the picked corps of officers of the great industrial army at a time when one of the great periods of development of our country has just closed, and when it is invading new territories and a wider field with hopes of conquest, when the opportunities are multiplying, it is true, but when, too, the aspirants to success are much more numerous. The days of irregular levies are over, those of a highly organized army with its sterner discipline have come. To a certain extent the individual now counts less in the lower ranks, and has become more powerful and is clothed with greater responsibilities as he enters the staff and rises to generalship.

The future lies with team work, and apparently the conditions under which the engineer must work out his career are changing. Our industries are destined to be controlled more and more by larger units, the modern consolidations. To give you a conception of the manner in which the work of the engineer and works manager is shaping, let me sketch an outline of the organization and the methods of such an enormous institution as the United States Steel Corporation. It is only within the last few weeks that I have been privileged to study these methods carefully, which, as you will see, bring into intimate relation the technical and commercial branches.

The United States Steel Corporation controls, through the ownership of stock, a number of companies which supply the raw materials, transport them, and convert them into a series of finished iron and steel products. Each one of the constituent companies of the United States Steel Corporation has its own organization, with its president, supported by a commercial and technical staff, the latter in charge of its manufacturing operations.

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It will be understood that a considerable number of the constituent companies do the same kind of work. Thus a number of them operate blast furnaces, others have Bessemer steel plants and other companies manufacture open hearth steel. There are a number of mills rolling the same finished product, although under the management of different constituent companies. It is evident that a central department can do much toward aiding in the improvement of practice and management.

The first step taken, in order to clear the ground, and in order to establish a basis for comparison, was to develop a common system of cost accounts, which should embody the best features of all. Meetings were held of the chief accountants of all the constituent companies. In many cases these men had already had much experience in selecting the best from the numerous concerns which had only shortly before been brought together through a consolidation. The completeness of the cost accounts varied greatly, from the famously elaborate Carnegie system to the complete lack of all data which survived in a few instances. The elaboration and working out of details was turned over to special committees of assistant accountants who reported back to the main committee, and thus finally the broad lines were agreed upon, covering the common ground, while each constituent company retained such features which its particular conditions made it desirable to adopt.

It is difficult to convey adequately what an enormous amount of work this involves, and how minutely and accurately costs are traced. Each constituent company has printed for its officers and accountants a book giving the main divisions and subdivisions of the accounts. One of these books contains hundreds of pages of closely printed type. In this manner the costs of the like operation at the different plants are reduced to a common basis and the extremely important work of making an analysis of them becomes possible. That work has now been taken in hand, and one by one the different manufacturing branches are brought within the sphere of the system.

By way of example, the blast furnace department may be selected The constituent companies of the United States Steel Corporation possess 76 blast furnaces. For each of these furnaces there is available a cost statement each month, which shows the cost of converting the raw materials, ore, coke and limestone, into pig iron. It gives such data, as—quantity pro-

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duced, quantity of coke consumed, labor cost of delivering the ore into the tunnel head, etc.

Of course the engineer must determine how to reach a fair basis for comparison between plants very differently equipped, and determine differentials, if necessary. Differentials may sometimes be necessary to put differently equipped works on a fair basis for comparison. Thus a manager who is using producer gas in his open hearth steel plant can not be expected to do as well as another who has natural gas. Experts determine what allowance is necessary, but it is a fact that some of the managers are actually beating natural with producer gas.

The different sheets in which the items are tabulated show the rank of each plant with reference to the others, and reveal the strength or the weakness of the management. Those whose plants lag habitually behind in the list can not be expected to be long connected with the company.

In the case of one department the plan has been developed further. The average of six of the best managed is taken, item for item, as the attainable cost. It devolves upon the managers of those plants whose figures exceed this to crowd them down to that attainable cost. They have before them the annual sum which their plant ought to save in order to come up to the standard of a whole group of plants and not one particular "crack" establishment.

An analysis of the costs having been made, the problem naturally comes up for solution—what methods should be adopted to bring about an improvement and make it effective.

To begin with, the comparison, or competitive sheets go to the president of each constituent company, whose natural ambition is to bring his plants and practice up to the highest pitch of cost efficiency and thus earn the maximum of dividends. Through him the technical staff have access to these comparisons and may note in detail in what respects they are in advance or behind their rivals.

In each special branch of manufacture, extending over a number of the constituent companies, there is a committee chosen from among the managers of that special branch. Thus there is a Blast Furnace Committee, an Open Hearth Committee, a Bessemer Committee, etc. Each committee meets to study and discuss the cost sheets, the methods of comparison, the differentials, etc., and hours are often spent over one item. A secretary is present at these meetings to keep a record of the conference,

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and collect such data and information as may be called for. This committee of managers also visits the different plants, in order to observe methods, exchange experiences, or make suggestions, being usually accompanied by a younger engineer as secretary who collects the data, etc. You may imagine what opportunities this affords the juniors. It will be readily understood that this system promotes the keenest rivalry and leads to unreserved criticism and open discussion. At first it repeatedly happened that the manager of one plant found it almost impossible to believe that results were at all attainable, such as were shown to have been achieved at other works. And yet it has occurred that within a brief period the doubter had himself secured like results or had even outstripped the record.

Besides the occasional visits of the managers' committee, individual superintendents are ordered by the president of a constituent company to study the plants of other constituent companies with the object of familiarizing themselves with details and looking into the question to what extent conditions warrant the introduction of improvements.

Nor do the general tabulations to which I have referred exhaust the means of discovering where leaks are occurring. The details of cost, too, are brought together for comparison, so that the source of the trouble may be traced minutely. Thus for instance the labor cost in the manufacture of pig iron is shown in a table which subdivides that single item in the general competitive sheet into 20 different items, so that discrepancies may be traced to the original source.

Contrast the rivalry thus created with that which existed for so many years among the managers of American blast furnaces and steel works, as to who was most successful in producing the greatest tonnage in one day, or week, or month from a unit of plant. Admirable though it was, it seems one sided and almost childish when compared with the struggle of showing the maximum results in profits.

I understand that experience has shown, that it is not by any means always the most magnificent plant, the most modern equipment, which carries off the palm for the best results in dollars and cents, and that the differences in the efficiency of management are truly astonishing. I am in the position to state (from data shown) that in one department the attainable cost, based on the average efficiency of a number of the better managed works, represented a possible saving of $3,270,000 per year, while the

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contrast between the practice of two very large concerns in another department represents an annual sum of $750,000.

Possibly the most important result of the team work which has been organized for the constituent companies of the United States Steel Corporation is its educational effect upon the whole staff of technical managers. A free exchange and a constant searching comparison of commercial results takes the place of secretiveness. One man's bent may lie in the direction of mechanical improvements, another's in the handling of men, that of a third in metallurgical manipulation, and usually a man likes to do what he knows he does well. Under the system developed under the auspices of the United States Steel Corporation, every one is kept on the *qui vive* in every direction. Every one is learning more in a month, than he ever before had an opportunity to acquire in a year, however much it may have been his custom to travel among his competitors.

Improvement is sought in other directions too by coöperation and by selecting the best talent for a particular service. Thus in a number of instances such details as the track system of a works has been remodelled and greatly improved by having one expert take the matter in hand.

Nor do the smallest details escape the vigilance of those who manage the manufacturing department, because what may seem locally of minor importance becomes large in the aggregate. Thus, recently there were called together a number of managers and chemists to study over the question of the consumption of acid in pickling, the total tonnage required by the corporation companies being very large. This committee has already discovered some very surprising differences in the practice, and is now busily engaged in collecting all the material available, as a preliminary to a searching and widespread reform.

What is being done in the constituent companies of the Corporation at large, is of course, going on in a similar way within the narrower special field of each of them. Every special little appliance, every minor manufacturing kink which each of the individual plants possessed and once jealously guarded, is now the property of all, and is being rapidly adopted. I understand that the elevation of the standard of efficiency which has resulted from this interchange of all that is best, has been very marked.

Only those who are in constant touch with manufacturing operations can appreciate what it means, when there are brought to bear upon the results, the close study and long experience of

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a number of engineers and managers, under the guidance of a master spirit. It is probably true that after the first general equalization has taken place further economics will come slowly. But, guided with tact, the rivalry among the different works managers and engineers will be a very potent influence in the direction of further progress.

You will observe, that however much truth there may be in the assertion that the trusts aim to suppress competition, their managers earnestly encourage it in their internal affairs, and that the engineering profession is to be one of the principal beneficiaries. I use that term advisedly because I believe that for the individual as well as for general interests the constant stimulant of rivalry is one of the greatest blessings. It may often seem irksome to be constantly crowded up to highest pitch of effort, but it is under such conditions that the best which is in a man comes out, and he is most likely to do himself justice. The system, too, seems to me to possess the great advantage that it affords the engineer the opportunity to note commercial results, and measure his efforts by the only true standard.

All this may smack of cold blooded materialism in which all higher ambitions, all greater ideals are thrust aside. But after all, the performance of what is a direct duty does not rob the engineer of the gratification of attaining those ulterior ends. After all, it is the engineer who has done most to raise the masses to a higher standard of physical well being, which is the foundation of increased happiness, of broader interests, and a higher humanity. With the spread of a better and higher education and with the growing certainty of possessing food and shelter at all times, we may feel assured that man will rise, although slowly. It is not the idealist who soars to heaven, but the earnest worker, in his appointed field, taking conditions as he finds them, and working at minor improvements, who will make the world better and better.

[The lecturer, Mr. Charles Kirchhoff, is Editor of the *Iron Age*, and an accepted authority in his department of engineering and of business. He is an alumnus of the Royal School of Mines, at Clausthal, and has had a large and varied professional experience which has given him exceptional familiarity with his subject. As Editor of the *Engineering and Mining Journal* and of the *Iron Age*, the two leading journals of their class in the United States, he has kept in touch with the mining and manufacturing industries very closely and has acquired very complete

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knowledge of all the details of their progress in later years. As a member and sometime president of the American Institute of Mining Engineers and as special agent of the United States Geological Survey for collecting statistics of the industries, he has had rare facilities for obtaining data and exact knowledge of the fundamental statistics of the national business.—EDITORS.]

STUDY FOR A RESEARCH LABORATORY.

Various plans for a Mechanical Laboratory, to meet the needs of Sibley College when it shall have expanded beyond the bounds contemplated in the original scheme of construction, have been proposed at various times, for many years past. It was, from the first, recognized that there should be erected, whenever the times were ripe and means permitted, some special structure which should lend itself fittingly to the requirements of a laboratory of mechanical engineering, of experimental engineering and of research in the field of industrial mechanics assigned by the statutes and the intent of the Founder to Sibley College. It was clearly seen that such a department would prove exceptionally fruitful of useful knowledge for the student, of helpful experience for the practitioner and of valuable work in the systematic application of mechanical science and of the sciences of chemistry and physics in the industrial arts It was presumed that possibly even invention and discovery might follow the opening of such opportunities to a large body of young men, all full of interest in their profession and of talent for their work and occasionally developing a genius for that higher work illustrated by Watt and Davy and Joule and Rumford, Sickles and Corliss and Greene. Even with the limited and unsuitable accommodations and apparatus of the laboratory in the past, something of this kind is usually in progress, and steam-engines, dynamos, tools and apparatus of many sorts have been produced as the outcome of the application of trained talent and native genius to the problems of the inventor and the designer in this field.

The first "Straight-Line Engine" was produced in Sibley College ; some of the most ingenious devices in rapid telegraphy were here developed in the earliest stages of those wonderful forms of apparatus ; inventions in great variety have been produced or perfected ; the world's record in efficiency of the steam-

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engine has been broken, and this new record is still a standing challenge to the world for engines of its size and type. Steam-turbines of a variety of kinds have been invented and constructed and tested. Scientific investigations of the performance of all sorts of mechanical constructions and devices have been made and the record of the work constitutes the most impressive, if not the most important, of all the claims of Sibley College upon the world, and especially upon the State, for consideration and honor and for generous support.

The unexpectedly, and almost alarmingly, rapid growth of the college has, from the date of its organization as a college of engineering, compelled constant construction and reconstruction and as constant modification of plans and of method. When the Founder was accustomed to talk of the time when there might possibly be a thousand students in the Sibley College, it was somewhat vaguely as of some far-distant generation. To-day, there are over 800 students taking work in the college, as candidates for degrees, baccalaureate, master's and doctor's and including a handful of special students. Should it prove that the flood cannot be stayed, there will be the full thousand students in two years more, no industrial catastrophe occurring to prevent their coming, and it should be possible to receive and properly care for them. This rapid and embarrassing progress has compelled careful study of the best methods of preparing for the impending contingency.

Several general plans have been contemplated as possible alternatives and the prime difficulty has been that of finding a proper site. It is preëminently desirable that all departments should be grouped as nearly about the main structure as possible. It is important, even more essential, if possible, that the prime movers, the steam-engines, their boilers, the steam-making and condensing apparatus, all sources and uses of power, be placed immediately under the eye of the responsible officer and adjacent to the shops and the other laboratories. Only thus can efficient operation be secured with an economical administration and convenient co-operation of one portion with another. But there is no really convenient site apparently available adjacent to Sibley College. It is situated on the bank of a deep gorge, is surrounded on the other sides by other buildings and no extended area upon which its expansion can occur is near at hand.

It was finally determined to endeavor to perfect two sets of plans, the one for a building to stand on level ground, the other

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to accommodate itself to the slope of the bank of the Fall Creek gorge, back of the present pile of buildings; although it was entirely uncertain where the first could be located and even less certain, as was at the time thought, whether the latter could be safely set on the slope. The plans were to be developed on the assumption that, by the time the buildings could be procured, the full thousand or perhaps twelve hundred students must be provided for by Sibley College. The appropriation must in any event be a considerable one and no one could say from whence it could be obtained; yet the enterprise should embody the noblest of opportunities to-day visible in our country in this field and should not be entered upon until it could be clearly seen that the success of the work could be absolutely and fully assured. A large structure was obviously certain to be needed and a considerable addition made to the equipment existing, as now provided for four or five hundred students, though compelled to serve, at present, for eight hundred.

Messrs Miller and Gibb, two well-known and successful architects, agreed to make a study of this problem and it was decided to prepare plans, though no immediate construction was hoped for and the future of the scheme was entirely uncertain. One of these studies, that of Mr. Gibb, has been substantially completed and we are permitted to give illustrations of the general plans and engravings of the proposed front.

This plan is adapted to the slope of the bank of the gorge and the surveys having been made, it was found, greatly to the surprise and satisfaction of the officers of the college, that it could not have been better adjusted to the requirements of the case had the ground been specially prepared to receive these buildings. The scheme proved so entirely practicable that the plans were hastened and the whole scheme fully developed, even to the location of the apparatus in detail, the architect giving much time and thought to plans in which he had come to feel intensely interested.

The frontispiece shows the elevation of the south side, the main entrance and façade, of the structure. The accessory structures lie on the slope of the bank, from the campus level to the edge of the stream, a hundred feet below. All the heaviest machinery, including the steam-power and hydraulic machinery, are placed at the lowest level, and the fuel and supplies are let down by suitable conveying apparatus, gravitation furnishing the necessary impelling force. Ashes and other material required to be brought up are

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raised by the same system. The sheltering banks insure defence against high winds and the adjacent stream gives opportunity to obtain all the water needed for use for purposes of experiment or for fire-protection, here so important a matter. The offices and class-rooms, and the laboratories for research and instruction in the departments employing the lighter sorts of apparatus, are placed in the main structure. On the east end is seen an attached, smaller, building which is intended for a locomotive-testing laboratory. When required, a similar construction may be adopted for the opposite end of the pile. The plans should provide for the instruction of Sibley College students satisfactorily when the roll numbers a thousand and it should be possible to organize quite as efficient a department of research within which to promote the highest of all forms of scientific work, the investigations of the whole field of natural phenomena finding illustration in modern industrial life.

"The term *original investigation* should be understood to include much besides experimental research. The writing of good technical books, for example, involves a large amount of original study and research, for such books should never be mere compilations. In the columns of one of our principal technical journals 73 technical books were reviewed during the year 1899, and 25 of these were written by professors in engineering schools. There is not a single technical journal, and perhaps not an important technical society publication, in the country to whose columns frequent contributions are not made by engineering educators. The current of progress of technical education is sweeping engineering professors farther and farther away from the old exclusive devotion to class-room instruction, and more and more bearing them into active participation in the daily outside work of their professions.

"The development of original investigation at technical schools has been especially rapid in late years along the line of experimental research. The modern methods of instruction require extensive and expensive laboratory equipment, which is also available for experimental research. The multitude of subjects pressingly needing such research is so great that energetic engineering instructors are naturally led into experimental investigations. Frequent reports of the results of such work are seen in the technical society proceedings. Also most engineering schools maintain regular publications, in which the results of many experimental investigations by both faculty and undergraduates are reported."

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"Such a technical school," adds Professor Marsten "should be one of the most potent factors imaginable for the betterment of the welfare of the people and for the progress of modern civilization." Cornell is such an institution in all its departments, professional and academic.*

THE "LATENT HEAT" FALLACY.

The accounts of the new ether vapor engine recently appearing in the Paris technical journals and one of which was reproduced in the *Scientific American*, January 4, 1902, revamp an old, and apparently still vigorous superstition among inventors. It is of such general acceptance and of such importance in its tendency to lead both inventors and investors astray and to waste time, talent and money, that it should be shown to be a fallacy so effectively that, among readers of the *Scientific American* at least, there can be no longer the slightest doubt.

In the article above referred to, it is said that the inventor of the new ether engine was induced to seek its perfection, being as stated, "struck by the theoretical advantages of ether over steam." The anticipated gain in the ether engine is assigned to the fact that whereas, in the case of the steam engine, in the exhaust "it has lost without utility the 971 British thermal units furnished to every pound of water in order to cause it to pass from a liquid to a vaporous state," this loss "may be notably diminished by using, instead of water, a volatile liquid that does not possess such great latent heat of vaporization."

So far from the truth are these statements that it would be more correct to reverse them. Rather than being a source of waste and loss of efficiency, so-called "latent" heat, and nothing but "latent" heat supplies the power of heat engines working in the most perfect cycle, attaining the highest possible efficiency and performing the largest possible quantity of work per unit of working fluid and of heat supplied from the fuel.

In the ideal gas engine of Carnot, the "perfect engine cycle" being employed, this transformation of energy affects the "latent heat expansion" of the gas and "latent" heat only; in the steam, ether, or other vapor engine, this heat, in the perfect engine cycle, with maximum possible efficiency, is the "latent

* Director's Report, 1901.

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heat of vaporization," and "latent" heat only. In neither case is sensible heat transformed at all; only "latent" heat is utilized.

In the gas engine of Carnot, every unit of heat entering the fluid in the progress of expansion is instantly converted into mechanical energy and work. The flow of heat into the charge occurs continuously at a constant temperature and the flow of energy out of the charge is just as continuous; and in the inflow of thermal energy and the outflow of its equivalent transformed mechanical energy, the one precisely balances the other, the air or gas neither gaining nor losing sensible heat in the process. The thermal line on the indicator diagram exhibiting this process is "isothermal." The Carnot cycle consists of a pair of isothermal lines, top and bottom, crossed by a pair of "adiabatics" along which no heat is either received from the furnace nor given up to the refrigerator and along which the heat stored by conversion into work during expansion is restored during the later compression. All the heat received by the charge is received at the higher temperature and wholly converted into work, and all the heat rejected is rejected at the lower isothermal in the process of holding down the temperature of the working substance to a constant minimum.

The principle of Carnot is thus complied with and all heat passing from the source to the working fluid is received by the latter at the highest possible temperature, at a constant temperature, and all heat rejected into the refrigerator, condenser or other receptacle for that heat, is rejected at a constant and minimum temperature. This may be paraphrased and we may say that, in the heat engine of maximum possible efficiency, the range of temperature employed is made, and is retained, a maximum entirely across the cycle. The difference between heat received and heat rejected is necessarily a measure of the thermodynamic conversion of energies.

The steam or ether vapor engine, working in the most perfect cycle, also complies with the Carnot principle. Its indicator diagram consists of a pair of constant-temperature lines, "isothermals" (which, in the vapor engine cycle are also lines of constant pressure), crossed by a pair of "adiabatics." The maximum temperature is that of vaporization. All heat leaving the working fluid leaves it at the temperature of condensation, at the lower limit of pressure, both of which remain constant during the process, and the line is both isothermal and of constant pressure. This rejected heat is that which, with reversal of this

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action, at that lower temperature and pressure level, would be the latent heat of vaporization at that lower limit. The pair of adiabatic expansion and compression lines do not either give the charge heat, from the source, or reject heat into the refrigerator or condenser; they temporarily transform heat into work in expansion, restoring it during compression, and all change of temperature in either direction is due to this action.

Thus all heat supplied for transformation into work is supplied as "latent" heat and the approximation of heat engines to perfection is the more complete as they evade the transformation of sensible heat and secure their mechanical energy by utilization of "latent" heat. The defect of the ordinary heat engine is evidently not that it employs a fluid having a large measure of so-called "latent heat," but rather that it does not employ "latent" heat and nothing but "latent" heat.

Carnot showed, as long ago as 1824, that, as he stated it, "the maximum of motive power resulting from the employment of steam is also the maximum of motive power realizable by any means whatever."

He further asserted, at that time: "The motive power of heat is independent of the agents employed to realize it; the quantity is fixed solely by the temperatures of the bodies between which is effected, finally, the transfer of the calorie.*

It has thus been perfectly well known for many years that the inventions by which it has been sought to evade the utilization of latent heat in the vapor engines, by substitution of other fluids, have been based upon a fallacy. In fact, the reasons given by these inventors for the use of other vapors logically compel the adoption of a gas for the heat engine, not ether, chloroform or ammonia, and the air engine should be substituted for all steam engines—if they are correct.

But while this is true and while, thermodynamically, there is no intrinsic advantage in the use of one fluid rather than another between two specified temperatures, and while the latent heat theory here criticized is a pure fallacy and quite the opposite of the truth, it does not follow that, practically, all substances are equally available for heat engines. There are other conditions and many controlling circumstances which determine choice. The subject has often been studied by engineers and men of science and, although it has commonly been concluded that, of all the available fluids, none is on the whole superior to water for

* Carnot, Thurston's trans. pp. 55, 68; N. Y., J. Wiley & Sons.

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this purpose, it does not necessarily follow that there may not be cases in which some other substance is more desirable or even that some other substance may not practically permit a larger transformation of heat into work. In the operation of heat engines, the temperature and pressure limits are always more or less fixed by external conditions and we cannot attain higher temperatures in the steam engines than those of steam of the highest safely controllable pressure, or higher pressures in the gas engine than those accompanying the highest safely controllable temperature ; nor can we adopt a lower temperature for our minimum than that of the external world. That working substance which most perfectly adapts itself to these limits and, within them, provides the best adjustment of temperatures and pressures and highest net return of work for heat, is economically best—always provided its use is consistent with highest financial returns and contributes to the production of good dividends by affording a decided profit over all costs.

Thus the fallacy of the idea of the inventors of the ether vapor and similar engines becomes evident. So-called "latent" heat is the desirable form of energy in heat engines. In fact, probably this confusion in the minds of the uninformed respecting "latent" heat arises from its unfortunate cognomen. "Latent" heat is, in fact, heat transformed into work and the work on the steam engine piston, for example, during the forward stroke of the piston up to the cut-off, is not performed by the steam in the engine, but by the steam at the instant forming in the steam boiler, which pushes out of its way the superincumbent steam and, through that displacement, pushes the piston, thus doing the work shown on the indicator diagram up to cut-off.

That this "latent" portion of the heat supplied is most efficiently utilized, rather than, as claimed, completely wasted, is easily seen by anyone who will take the trouble to compute—as did Mr. G. H. Babcock many years ago †—the weight of steam per horse power hour required by even the ideal engine, under common conditions of temperature and pressure, assuming all "latent" heat wasted and only the sensible heat taken up by the feed-water being thermodynamically utilized. It will be found that, in the example taken, nearly 90 pounds would be demanded, where the "perfect-engine cycle" would do the work on less than 10 pounds. Again, a steam engine receiving 20 pounds of steam

† Manual of the Steam-Engine, Vol. I, Sec. 112.

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per hour would only thus receive about 200 B. T. U. per pound, 155,600 foot pounds of energy, or less than one-tenth horse power per pound, 2 horse power from 20 pounds, of which it might utilize one-eighth. In other words, "latent" heat performs the principal part of the work in the steam engine.

The volatile fluids, like ether, ammonia, chloroform, carbon disulphide, sulphur dioxide, etc., may prove to have their uses in heat engines, but for quite other reasons. They may permit the utilization of low-temperature heat in paying quantity. This, at the moment, is a question which is particularly interesting the engineer in view of the claims based upon the Berlin experiments of Prof. Josse.

To utilize low-temperature heat, if we are to find that profitable at all, we must employ other fluids than steam, simply because, at those low temperatures at which we exhaust steam from the cylinder, ordinarily, the pressures are too low to drive our machinery and because the size of engine required to handle the steam for any stated power becomes enormously and impractically large. A working fluid giving the general action of steam, but with comparatively high pressures at and below the temperatures of exhaust of the steam engine, if unobjectionable on the score of cost, direct and incidental, or of danger or serious inconvenience, might add a large fraction to the power derivable from the unit of heat or of fuel employed. This last is the line of improvement which has been sought so often during the past two generations by inventors of the "binary-vapor engine." It is here, if anywhere, that the volatile liquids may find their place in the heat engines.

This field of invention is open to all. The idea is very old and such patents as are fundamental have probably all long ago expired, leaving the would-be inventor entirely free to seek a way of utilizing low-temperature heat in volatile fluids and high-temperature heat equally far removed, apparently, from the range of the ordinary steam engine by the employment of other fluids appropriate to that higher portion of the scale of temperature.—R. H. THURSTON, *in Scientific American Supplement.*

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The *Biologischen Centralblatt*, in reviewing "Kinematics in the Animal Kingdom," by F. Reuleaux, makes reference to Dr. Thurston's "Animal as a Prime Mover," translated by Reuleaux in 1895. We have translated the portion in question.

THE POWER OF THE MUSCLES.

The muscles correspond with the engines or motors of the engine-builder. The American engineer Thurston says of them:

"The value, which the living machine has for the engineer, is extraordinarily great, although it is rarely estimated completely, or even obtained by use.—The theory of this living engine, and study of its methods of work, its energy-transformation, and economical use form one of the most essentially practical problems, which are placed, now before the engineer, again before the naturalist, and indeed from two quite separate causes.

In the first place, the living engine has a higher efficiency of operation than any steam engine, and includes methods of changing, storing and converting energy, which are yet secrets, and which, if once explained and carried out in engine practice, would prove themselves immeasurably more valuable for the improvement of the customary methods of procedure, than was the invention of the present steam-engine over the old engines of Worcester and Savery. Thus it is possible, that the ways in which light, electricity and mechanical work are produced, will prove themselves disproportionately economical as compared with those which concern mankind. At all events, the latter are widely separated from the former, and incomparably richer in effect in themselves; and as transformations, far simpler than any pattern yet discovered by science.

"In the second case, it is not impossible, if once the laws of operation of the living engine become completely explained, that we can find means to transfer the animal mechanisms into our engines, and means to apply what in them does such remarkable service to the operation of the machinery."

These words of a practical American characterize quite sufficiently the great practical meaning to engineering science, of physiological investigations, and make it intelligible why such an engineer as Reuleaux has bestowed so much time and energy upon the solution of one of the most difficult problems of the physiology of animals' bodies.

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SUBSCRIPTIONS for the JOURNAL are now due. These may be mailed or handed to L. S. Haskin, 1½ Central Avenue, Ithaca, N. Y. The JOURNAL asks that payments be made promptly, since its creditors make the same request.

The N. Y. Tribune, of January 18th contains a long advertisement in its reading columns in which the schemes of a new trans-Atlantic steamship company are promoted, and in which is included a remarkably bold forgery, a commendation of the plan purporting to be an extract from a discussion of the steam-turbine by Dr. Thurston before the American Society of Mechanical Engineers. Such a paper was read before that Society but without a word regarding the device of the promoter who who publishes the forgery, for the very good reason, as the writer of that paper states, that he had never heard of either the promoter or his machine.

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Department Notes.

Mr. George L. Hoxie, instructor in Electrical Engineering, has resigned, to accept a position with Messrs. Westinghouse, Church, Kerr & Co., of New York City. The vacancy was filled by the appointment of Mr. George S. Macomber. E.E. '00, who, after graduation, spent five months with the Pittsburg Central District and Printing Telephone Company. He then received a call from the Washington University, Saint Louis, Mo., where he was an instructor in the departments of Physics and Electrical Engineering until he came here.

A Cornell man writes :— .

"At present I am in the detail engineering office, developing a line of electrically operated switches and doing other engineering work requiring a thorough and practical knowledge of electricity and mechanics, which I think is a class of work granted to very few apprentices. I would like to emphasize the points mentioned in an article in the SIBLEY JOURNAL of April, 1901, in regard to the great value of *early* and thorough practical work for technical graduates."

The wood-working department of the Sibley shops has been rearranged during the holidays, and some sixty lathes are reported to be now in use, the great majority of which have been made, as called for, in the machine-shop. It is thought that the work-shops have about reached their limit in expansion for the present and, in junior work, there are not now tools and machinery enough to accommodate fully the largest sections.

Mr. Max H. Miner, instructor in Mechanical Laboratory, has resigned to accept a position as associate editor of *Railway Age*, with his headquarters in New York City. The position was filled by Mr. Harry L. Hepburn, M.E., '97, who has been with the Taunton Locomotive Works ever since graduation, leaving them with the rank of chief draughtsman and consulting engineer, to come back to Sibley.

Railway Age of February 7th describes and illustrates the reducing motion for indicators, used on locomotive tests by the School of Railway Mechanical Engineering.

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Personals.

'96. Mark W. Roe, M.E., is at present in the employ of the Stirling Boiler Works, at Barbourton, Ohio.

'97. Frederick Henry Hayn, E. E., has recently been appointed 4th assistant examiner in the United States Patent Office, Washington, D. C.

'00. Charles W. Bergen, M.E., is in the mechanical engineering department of the New York Central R. R. Co., with headquarters in New York City.

'97. Leo Ammann, E.E., is instructor in drawing, pattern-making, and moulding in the Saint Louis Manual Training School, his address being Highland, Ills.

'92. W. E. Goldsborough, E.E., writes Dr. Thurston as follows: "It gives me great pleasure to inform you of my appointment to the position of Director of Electrical Exhibits at the St. Louis Exposition, and to express to you again my hearty thanks for the good offices extended by you in my behalf in this connection." He is Professor of Electrical Engineering and Director of the Electrical Laboratory, in the School of Electrical Engineering at Purdue University, Lafayette, Ind.

'89. F. M. Whyte, M E., now Mechanical Engineer of the New York Central R.R., presented before the Western Railway Club, on Dec. 17th, 1901, a paper entitled: "The Man for the Work, the Specialist; and the Man who Thinks." We will quote a short synopsis, with which the paper was prefaced:—

1. Decide upon the work, either mental or physical, which is to be done, and select the man for it; rather than adapt the work to the man.

2. Bring necessary and similar work together in the largest quantities possible, and provide for doing it such particular supervision and facilities as are commensurate with the amount to be done.

3. Instructions and information from the responsible head must be concise and at the same time explicit and complete, and certain to reach the man who does the work. Similarly, the reports must be concise and complete, and certain to reach the responsible head.

4. The man who thinks for himself and thinks in unision with others who are interested in the success of the organization is soon given an opportunity to show whether he can think for others also.

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'90. S. B. Fortenbaugh, E.E., (M.M.E., '94), writes Dr. Thurston from London, in part as follows: "Since writing last summer, I have associated myself with the Yerkes interests, as their Electrical Engineer, and will probably remain here for some time for the valuable experience. Mr. Yerkes now has control of five different underground roads, one of which is operated by steam, one is building, and the remaining three are yet to be built. When completed we will have about 60 miles of double track, and operate about 150 five-to seven car trains. We are now pushing along the plans for our power house, which is to have a normal capacity of 50,000 Kw., and about 20 sub-stations. We will have ten turbo-alternators in the power house—each of 5000 Kw.—each set to consist of a two-pole alternator, direct-connected to a Westinghouse-Parsons steam turbine, operating at 750 r.p.m. Our first job is to re-equip the District system with electric traction, and we hope to have it changed in about two years. The system comprises about 40 miles of double-track, and is both underground and surface work.

"New Year's night we had a little Cornell dinner here in London. Messrs. Shiras, Wild, White, Rogers and myself, (all Sibley men) were present, several others being unable to attend. I think we are bound to grow, in time, and hope to have more next time."

[EDITOR'S NOTE.—The large generators at Niagara Falls are of 5500 horse-power, or 4100 Kw. The newly designed generators for the Canadian Niagara Power Co's plant will be each of 10,000 horse-power, or 7460 Kw., and are by far the largest single units yet projected.]

BOOK REVIEW.

FURNACE DRAFT: ITS PRODUCTION BY MECHANICAL METHODS. By WILLIAM WALLACE CHRISTIE, A.S.M.E. Published by the author at Paterson, N. J., and by D. Van Nostrand Co., New York, 1901. 42 pp. Price 50 cents.

This little volume is largely a compendium of tables and rules for use in the designing of chimneys and other draft-producing appliances. While specially disclaiming all pretensions to completeness, it includes in a very small compass a large amount of data and other information on its subject. It should form a valuable book for reference. Among the authorities quoted may be mentioned Dr. Thurston.

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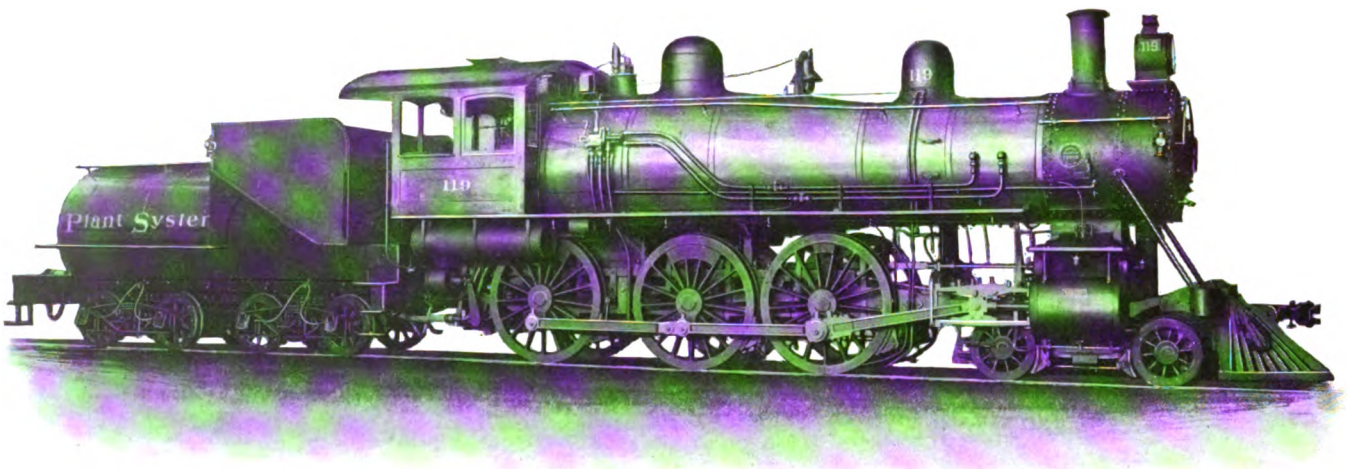

THE 20,000TH BALDWIN LOCOMOTIVE.

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THE SIBLEY JOURNAL OF ENGINEERING.

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IN CORNELL UNIVERSITY.

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislature of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

THE PREMIUM PLAN OF PAYING FOR LABOR.*

F. A. HALSEY, '78.

Broadly speaking there are two methods of paying for labor in common use. Under the first method payment is made in proportion to the amount of time consumed in doing the work, while under the second, payment is made in proportion to the amount of work done. In the vernacular of the shop these are called respectively the *day's work* and the *piece work* plans.

A third plan deserves attention—not because of its connection with the subject but because of its intrinsic importance. It is, in a sense, a combination of those named and, measured by the extent of its use, it is next to them in importance. I refer to the New England Contract Plan under which certain leading men—who are sometimes called foremen and sometimes contractors—are given contracts for doing certain work. The shop and its facilities are the property of the employer, but the contractors proceed much as though the shop was their own. They engage the help and arrange their rates of pay—this pay being by the day, the men as a whole having no interest in the contracts.

* Lecture delivered before Sibley College, February 7th, 1902.

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The contractors are not capitalists and do not furnish the capital or pay their men, who are paid by the employer precisely as though there were no contract plan in the shop, but the wages as paid are charged against the various contracts and as the work is turned in the contractors are paid the difference between the contract price and the wages paid out.

There is no question that this plan has had a large influence on the development of the metal working industries of New England. It has, moreover, extended far beyond the confines of New England. Some very large works—among them the Baldwin Locomotive Works—operate on this plan.

Inquiry regarding this plan will frequently be baffled by its contradictory aspect to the different parties. To the employer it is piece work, as he ultimately pays for the work by the piece, and he will frequently call it by that name. To the workman, on the other hand, it is simple day's work, with the addition of an unusually energetic and lynx-eyed foreman. Except as he learns it accidentally, he need not even know that the shop is at bottom a piece work shop, as his own rate of pay, as well as that of his associates, is exclusively by the day.

The day's work and piece work plans are, in their leading faults, antithetical. From the nature of the day's work plan the workman has no direct share in any increased production which he may bring about by more intelligent or increased exertion—the benefits of such increase going wholly to the employer. The only inducement the workman has toward increased effort is the hope that, through it, he may eventually obtain a slight increase in his daily wages.

From the nature of the piece work plan on the contrary, the employer has no direct share in any increased production which the workman may bring about by more intelligent or increased exertion. He has the indirect benefit due to the increased production from a given plant, but the wages cost remains the same regardless of the production.

I have spoken of these features of the two plans as their chief faults and they are such because, through them and in consequence of them, community of interest between employer and employee in the reduction of costs is impossible. Neither offers any basis for such a community of interest and it is this which it is the prime object of the premium plan to supply. The piece work plan has upon its face the appearance of equity and fair dealing. "It pays for the work done and in proportion to what

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is done. The industrious are rewarded in accordance with their industry" etc., etc. The universal opposition of labor unions to it is looked upon as another evidence of their total depravity. Of course, in so far as the objections of the unions are a reflection of the opposition which some of them have to their members doing a large amount of work, it cannot be defended and is not worth discussion, but for other reasons and on other grounds their position of opposition is impregnable. Near acquaintance with the system shows that it is not what it appears to be. It is, in fact, a remarkable illustration of how completely a thing may differ in appearance from what it is in reality. It is, in appearance, a system of rewards, but it is, in fact, a system of punishments and, worse still, a system of *punishments for doing well.*

As this is a severe arraignment it requires an examination of the actual workings of the system. A piece of work has been done by day's work and it is proposed to change it to piece work. The piece cost* under day's work is first determined and a somewhat smaller piece price is then set and given to the workman. If he has had no experience with piece work he feels that he cannot "make wages" and objects. He is then told that if he will not take it some one else will—in other words he is compelled to take it, and this is the first objection to the plan—it involves compulsion. If this were all that could be said against the system it would not have much weight but it is nevertheless worth noting. Leading is always better than driving and compulsion is a good thing to avoid if possible.

No man knows what he can do under an incentive until he has tried it. The workman in saying that he cannot "make wages" at the piece prices offered when piece work is first introduced, is entirely sincere but he is nevertheless mistaken. All experience shows that when the test comes the increase of output under the incentive of piece rates is far beyond what anyone—manager or workman—would have believed possible. The output mounts up and the wages with it and the employer soon finds that he is paying an extravagant rate of daily wages—an extravagant rate being understood as a rate materially in excess of what it would be necessary to pay another workman for doing the same work, he having the first man's experience before him. The employer submits to this for a time but the wages continue to increase and ultimately he is driven to his only recourse—he cuts the piece

* The actual wages paid for doing the work, or the "wages cost" only, is considered here.

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price. This is an immediate announcement to the workman that the promises of piece work are false. He was told that he would be paid a certain rate per piece, but he finds that to be true up to a certain limit only. The workman, again under compulsion, accepts the new price but, unless he is very dull, he has learned a lesson. If he is very dull it may require a second cut to enforce this lesson, and this second cut, either on the price of his own work or on that of some fellow workman, is soon forthcoming. The lesson is that if he pushes his production to a point which raises his earnings beyond a certain more or less clearly defined limit the direct result will be a cut in the piece price. Perhaps new men come in or the old ones are given new work to do—the result is the same. If any one is so unwise or so unfortunate as to do a large amount of work he is at once punished for it by having his rate cut. Such cuts from the workman's standpoint have one result—he is compelled to work harder than before but he earns no more. This is the result of his own efforts to increase his output and hence it is that I call the piece work system a system of punishment for doing well.

The net result of the system is a somewhat greater output and somewhat higher wages than would be obtained with the day's work system but there is no spirit of progress. The workmen push their earnings as near to the limit as they dare and then stop making further effort to increase their output. If one man has several pieces of work, on some of which the prices are high while on others they are low, he makes out false time tickets, charging time to one job which belongs to another, so as to equalize matters and give a fair average and thus take advantage of the high rates on some pieces to equalize the low rates on others. The whole tendency is to cultivate deceit and antagonism. The piece work plan is, in short, simply a mischief maker and a discord breeder.

The workman, of course, looks upon these cuts as an exhibition of pure hoggishness on the part of the employer. While the employer may take undue advantage in this way, the fact remains that if he does not make the cuts from choice he will eventually do it from necessity, for it can be shown that these cuts are an integral part of the piece work plan, which can no more be operated without them than a wind mill can be operated without wind, and for the reason that as the years go by, the whole tendency of prices is downward. There are of course periods of advancing prices but they are short lived, and are nothing but the incoming waves of

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the receding tide. The tendency through a series of years is downward and this must be so. It may almost be said that this is what industrial civilization is for—to make things cheaper. The whole industrial world is engaged in a ceaseless effort to reduce costs in order to reduce prices and with so much effort it would be strange if there was not some success. With this future of falling prices before him no manufacturer can contemplate paying the same piece rates ten years hence that he does today. In normal times most manufacturing enterprises are conducted on a small margin of profit and, with a future of falling prices before him, no manufacturer can continue to pay materially more per piece for his work than his competitors pay. The simple fact is that uncut piece rates lead to rates of wages which, under the conditions of competition between manufacturers, cannot be maintained. Of this more later.

The day's work and piece work plans are, as has been shown, antithetical in their faults and the premium plan is an effort to obviate these faults by, so to speak, splitting the difference between them. By this is meant that, whereas with the days work plan the immediate gains due to increased effort by a workman go to the employer, while with the piece work plan they go to the workman, with the premium plan they are divided between the workman and his employer, and this is the essence and substance of it.

To understand this, suppose that a piece of work has been done upon the day's work plan and that it is proposed to change it to the premium plan. The time which it has required is determined, and the workman, who is still paid the old day rate, is told that if he will reduce that time he will, in addition to his daily wages, be paid a premium for each hour or part of an hour by which he reduces the time—*this premium per hour being less than his hourly rate of wages.* Please note this, as it is by this device that the division of the gains is made. If he objects he is simply told, "Very well, try or not as you think best—there is the work and the offer, and the premium is ready whenever you have earned it." In other words the proposition is simply an offer of a reward for an increase in output without a trace of anything in the nature of compulsion. It is, of course, expected and usually found that, with this reward before him, the workman will sooner or later endeavor to increase and succeed in increasing his output.

Formerly I had an idea that this absence of compulsion and

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the fact that each workman may elect to work for premiums or not as he chooses, would obviate objections by the unions but in this I have been disappointed. There is, however, a difference between the opposition of the unions to this system and their opposition to piece work. To the latter system the opposition is both official and personal, while to the premium plan it is chiefly official. At the start, individual workmen are usually opposed to it. They look upon it as piece work in disguise, and they have been victimized so many times by that plan that no one can fairly criticise them for their hesitation. After they learn that the promises of the new method are honest, it is uniformly popular, as it is hard to see how it could be otherwise, the men often asking for premium work faster than the management can arrange to give it out. My hope and belief is that eventually the unions will accept it as individuals have done.

To gather the exact workings of the plan assume a concrete case. A workman is paid (say) $3.00 per day and produces one piece of a kind per day—that is in 10 hours. He is told that he will continue to be paid his $3.00 a day as before but that if he will reduce the time on the piece he will be paid in addition to his wages a premium of 10c. for each hour saved. If he reduces the time by an hour that hour represents in money value a gross saving of 30c. Ten cents of this amount is paid to him as a premium, leaving the remaining 20 cents in the employer's possession—this sum making itself manifest in the reduced cost of the work. If the workman goes on reducing the time in which the piece is made, the same process is repeated, each hour saved resulting in an increase in the workman's wages of 10c. and in a reduced cost of the piece of 20c. In other words the wages go up and the costs go down simultaneously, this apparently paradoxical result coming about from the fact that the gross time saved is divided between employer and employee, part of it going to increase the wages of the latter, and the remainder going to reduce the cost to the former. This is shown in the accompanying table, which, for purposes of illustration, is extended until the workman has doubled his output, in which case the (wages) cost of the work has gone down from $3.00 to $2.00 while the workman's earnings per day have advanced from $3.00 to $4.00.

There is, of course, a considerable gain to the employer due to the increased production from a given plant, since the secondary costs of production—the expense items which make up the burden

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THE WORKINGS OF THE PREMIUM PLAN.

1	2	3	4	5
Time consumed	Wages per piece	Premium	Total cost of work =col. 2+col. 3	Workman's earnings pr. hr. =col. 4÷col. 1
Hours	Dollars	Dollars	Dollars	Dollars
10	3.00	0.	3.	.30
9	2.70	.10	2.80	.311
8	2.40	.20	2.60	.325
7	2.10	.30	2.40	.343
6	1.80	.40	2.20	.366
5	1.50	.50	2.00	.40

and which must be added to the cost of labor and material in order to obtain the ultimate or true cost—are increased but little in consequence of the intensified production. It is, however, easy and customary to exaggerate the employer's gains from the system, a subject that will be discussed more fully further on.

It will be seen that, superficially, the plan has some resemblance to the profit sharing plan. The chief difference is that whereas the profit sharing plan treats the business as a whole and the workmen in a body, the premium plan treats each individual and his work separately. Under the profit sharing plan, the gross profits at the end of the year are determined and a certain percentage of these is divided among the workmen regardless of individual merit, whereas, under the premium plan each workman's earnings depend solely upon his own efforts. The profit sharing plan could be discussed at some length, but, in as much as it has now nearly dropped out of public attention, little will be lost by passing it by. It is easy to show that, while the spirit of the plan is commendable, it can not produce the results of the premium plan and that, moreover, it is economically unsound.

As outlined above the premium plan is a very simple thing—an almost absurdly simple thing, and it would seem to be so obviously correct in principle as to be accepted without question. It has, however, required much time and effort to get it tried. It is now being tried, however, on a scale which will determine its merits and insure its permanancy if it is really what it appears to

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be. No very exact idea of the extent of this trial can be given, as interested parties, who at first came to me for information and suggestions, now go to their friends. It is known to be in use in the United States, Canada, England, Scotland, Germany, Italy and Belgium. Interest has been shown in Sweden and Austria, but it is not known to me whether the plan is in use there. It has apparently attracted more intelligent and serious attention in Great Britain than here or elsewhere—a fact which may perhaps be due to the considerable feeling there that British industrial methods need improvement.

Since the plan has come into use several changes in the method of dividing the value of the time saved have been suggested and used. One of the largest users of the plan—in Glasgow, Scotland—divides the value of the time saved by increasing the workman's rate per hour by the same percentage that he reduces the time—that is if he reduces the time by ten per cent. his hourly rate is increased by ten per cent. and so for other rates of saving. Another English user of the plan tempers the wind to the shorn lamb by providing for different grades of men. He assumes that two men who are paid different rates for doing the same work are so paid because they produce different amounts. He considers it to be unfair to ask a slow workman who is paid a low rate of wages to equal the output of a rapid high priced workman before he begins to earn premiums. He therefore uses a highly ingenous method by which the base time is automatically extended in inverse proportion to the rate of daily wages—a $1.50 man, for example, being allowed just twice the base time that a $3.00 man would be given. Still other methods have been used. These changes do not affect the essential principle, but they make it desirable to define accurately just what the premium plan is and the following is such a definition :

The premium plan is that plan or any plan by which the gains due to increased production by a workman are divided between that workman and his employer.

As regards the relative value of these various methods of making the division, I regard such considerations as of comparatively small importance. The case is comparable to that of a steam pipe covering—though the analogy may not be obvious at first sight. Any good steam pipe covering will, I suppose, save 80 per cent. of the condensation due to a bare pipe, while the best one will not, I suppose, save over 90 per cent., and the merits of different coverings, as regards the saving made, fall within

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these narrow limits. Of course steam pipe coverings have other points of merit, such as cheapness, durability, accessibility, renewability, etc., and so these methods of division have varying degrees of merit as regards simplicity, adaptibility to conditions, etc., but, in the matter of the steam pipe, the important thing is to get a covering on it, and so regarding a factory, the important thing is to get a premium into it, and whatever covering or method of division is used, it is safe to say that it will do about 90 per cent. of all that is possible, by any modification. If an employer prefers any one of these plans he should by all means use it, but he should not consider it to be a matter of any large importance.

The first question to be decided after the adoption of the plan has been determined upon is the rate of the premium—that is, what proportion of the value of the time saved is to be given to the workman who saved it.

For this there is a perfectly clear principle to guide us and that principle is precisely the one which we use in buying anything whatever with money, viz., to pay what is necessary to get what is wanted but to pay no more. If we have a fence to paint or a roof to shingle, the only principle we ever think of following in order to get the work done is to pay enough to induce someone to do it. If we offer less than that, the work will go undone, while if we pay more the surplus is a simple gratuity. So here. A workman has been working at the usual pace and has been paid the usual daily wages. If we wish to induce him to do more, we should offer enough as a premium to induce him to make the extra exertion, and no more. If we offer too little he will reject the offer, the offered returns being too small to recompense him for the effort and the desired increase will not be obtained. On the other hand, if we offer too much, the surplus, as in the case of painting the fence or shingling the roof, is a simple gratuity.

Looked at from this standpoint it is clear that there can be no single rate of payment which will apply to all classes of work. In the machine shop, for example, increased output is largely a matter of intelligence. The workman uses coarser feeds, higher speeds and deeper cuts. He has several tools at hand and grinds one while another is at work, so that, as soon as one is dull, another may be slipped into its place without loss of time. In other words, he crowds the machine rather than himself. In the blacksmith shop or foundry, however, increased output can be secured only by actual increased muscular effort by the workman. It is

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clear that in the first instance a smaller premium will suffice than in the others.

I have always considered this feature of the plan, whereby the incentive can be graded according as the work is laborious or not, to be one of its best features, though it has attracted less attention than it deserves.

Looking at the premiums when settled in accordance with this simple principle of paying what is necessary but no more, we learn several things, of which the first is that they are in no sense bonuses or gratuities, but that, on the contrary, they are, in the fullest sense of the word, earnings.

As well call the increased earnings of the American over the European workman gratuities as to call these premiums by that name. We are all glad to believe that the American workman is more efficient and that he earns more money than the European workman, though the fact is explained in different ways. The free trader explains it by saying that the American gets more because he does more, while the protectionist simply reverses cause and effect and says that he does more because he gets more. Both agree, however, that the increased output and the increased earnings go together and that the one justifies the other, as indeed is self evident. The premium plan simply carries the process a step further and proposes a permanent increase in the efficiency of labor, and if efficient labor is worth more than inefficient labor, then the premiums paid for and to secure increased efficiency are absolute earnings and in no possible sense gratuities.

In this connection it should be said that the name "premium plan" is not and never has been entirely satisfactory, because the term premium carries with it the idea of a bonus or gratuity. I searched the English language through for a better term, and for a time I had a leaning toward the term "dividend plan", because the word dividend implies a division of something that has been earned. The word is, however, identified with a division of profits, and to have used it here would have involved confusion with the profit-sharing plan. The word "premium" was therefore adopted, not because it was satisfactory, but because it was less unsatisfactory than any other available word.

Looking at the premiums when settled in this way, we learn, secondly, that they do not need to be cut from time to time, but that, so long as the methods of production do not change, the rates may be permanent. The plan contemplates increasing the workman's earnings as a reward for increased effort by himself.

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Should the proprietor introduce a new labor-saving machine, it would be economically wrong to continue the old rates, since the increased output of the new machine is not the result of the workman's efforts. Under such circumstances a new base time must be determined and the premiums be based on that.

If the rates have been settled in accordance with this principle there need, however, be no change in them so long as the methods of production remain the same, and indeed there must not be. Such cuts would introduce the objections of piece work and destroy the workman's confidence in the system and with it his incentive to further effort. To cut the rates is to kill the goose that lays the golden egg. It is essential that the limit to the workman's earnings shall be set by his own capacity to produce, and not, as with piece work, by an arbitrary ruling of the office.

It has often been objected that the proprietor may cut the rates if he chooses and that after all the plan still has the same fundamental objection as piece work. True, the plan does not make rate cutting impossible, but it does make it unnecessary and unprofitable. Smaller initial rates than those determined by this principle would have been less profitable to the employer, and to cut them when once set would not only lead to less profitable rates, but it would stop further progress by destroying the workman's confidence. Under this plan it is to the employer's interest not to cut, while, as has been shown, under piece work such cuts are sooner or later forced upon him.

With the rates set in this manner we see, thirdly, that with a single limitation we have secured an ideal economic condition—a condition under which and under given methods of production, we will obtain the highest possible production and the lowest possible cost, while the workman will receive the highest wages to which he is economically entitled. In other words, we will secure the maximum possible efficiency of plant.

The limitation referred to is this: In all this we are at bottom depending upon the intelligence, ability and initiative of the workman to increase his output. Mr. F. W. Taylor has put into use at the Bethlehem Steel Works a rate-fixing department and a system of instructions to the workmen by which they are told just now to produce the maximum output. With a given amount of material to come off of a given piece of work there is a certain combination of feed, speed, depth of cut and shape of tool that will accomplish the work quicker than any other combination. This combination depends largely upon the material operated

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upon and upon other conditions, and its determination is a matter of extended inquiry, expert analysis of data and expert calculation. It is not to be expected that the average workman will be able to find this combination as accurately as one specially skilled at it and, where conditions favor, I have no doubt that Mr. Taylor's method will produce better results than can the unguided efforts of the average workman. Mr. Taylor has devised a system which meets the peculiar conditions with which he was surrounded, with remarkable success, but I do not believe that it is of wide application.

Considering the premiums as set in this way and considering also the rates which experience shows to be sufficient, we learn, fourthly, the fundamental defect of piece work—*its initial incentive is too high;* that is, it offers a reward for increasing the output which is larger than is necessary to produce that increase and larger than it is economically possible for the employer to continue to pay. It is from this defect that all the difficulties with piece work spring. Cutting the rates is a clumsy and disastrous method of correcting this defect.

When it comes to the actual setting of the premium rates, it must be owned that our guiding principle gives us but little help, but that is equally true of it as applied elsewhere. The real difficulty we have to face is that, whereas if we have a fence to paint or a roof to shingle, we have a large body of experience to draw upon, in the matter of premiums the body of available experience is small. In the one case the custom of the locality settles for us what rate we must pay, whereas in the other, custom has not yet been established. In this matter I am satisfied that the tendency is to set the rates too high—that is, to set them so high that in the future the employer will be apt to find, as with piece work, that another workman would be glad to take the work at a lower rate, if that rate were guaranteed. The premium rates actually paid range between one-third and one-half the wages rates. The former figure for machine shop work I regard as about right, but the latter, except in shops which were under a high state of efficiency before the adoption of the plan, I regard as dangerous. In my own use of the system in Canada the highest rate paid to men was one-third the wages rate, and it ranged from this down to one-quarter, and this rate seemed there to be ample, although the lowest of which I have any knowledge. At the same time everything in the way of wages, salaries and incomes is on a smaller scale in Canada than here, and the rate would probably be too low here.

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A further divergence of practice exists regarding these rates. The usual practice is to give all workmen a fixed percentage of their wages rates—a practice which, of course, makes most of the rates fractional, and thereby adds to the labor of calculating the premiums. Mr. A. A. Fuller, of Providence, R. I., after several years' experience with the system at the Builders' Iron Foundry—which is not a foundry, but a machine shop with a foundry attached—had an opportunity to apply his experience and start anew at the Providence Engineering Works. At the last named place he adopted a fixed rate of 8 cents per hour for all machine shop labor—a rate which is one-third the wages rate for men getting $2.40 a day, and probably averages about one-third for the entire force This method avoids fractions in the rates, and, moreover, it is divisible by 4, and inasmuch as time records are not kept more minutely than for quarter-hour periods, fractions never enter the premiums at all, which is a great convenience in the bookkeeping. My own practice in Canada was similar to this, except that the rate was uniformly 5 cents per hour, and I had a second rate of 3 cents for apprentice boys. Others, as already explained, have adopted quite different methods of calculating the premiums.

As regards a general proof that the system really works as outlined, I have always regarded such proof as superfluous. It seems to me about as necessary to prove that water will run downhill as that men will work for money, or that they will work harder for large amounts than for small. It must be remembered that if the system fails to work, the results are simply nil; that is, the results must be either positive or zero; they cannot possibly be negative. Either the system increases output, reduces cost and increases wages or it simply does nothing. In other words, no risk, beyond some trifling initial expense, is involved in giving it a trial.

The question of the extent of the gains made is, of course, a legitimate one. Several tables giving comparisons of the three items affected before and after the adoption of the system have been published and the gains are uniformly greater than would be believed possible. In one case a certain corporation, whose name I am not at liberty to give, had made thirty-five large, heavy machines and at a later date they entered upon a second contract for twenty duplicates which were made under the premium system—the base time being taken from the cost records of the first machines. At a certain stage of progress with the second lot I

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was given a table of the records of the two contracts—the figures given including all records - good and bad alike—that had been made on the second lot. The extent of the exhibit is shown by the fact that the time reported in it for the first contract aggregated about 20,000 hours. Taking the time, wages cost of the work, and wages earned per day on the first contract as unity, the second contract showed a reduction in time of 43 per cent., a reduction in the wages cost of 25 per cent. and an average increase in wages per day of 29 per cent.

It is scarcely possible to collect data of any kind from the results of every day work which are, in all respects, satisfactory. It is especially difficult to preserve that fundamental condition of all intelligent experimenting that but one condition shall be varied at a time, and candor requires it to be said that this criticism applies to this exhibit. In the nature of things one of these lots of machines came first chronologically. A piece of work done the second time is usually done with a reduction in the time expended, and other things being equal, the second lot of machines, without any premium at all, should have shown some saving in time and cost. Other things were not equal, however, the second lot being for twenty machines while the first was for thirty-five and in these matters the advantage goes with the larger lot which should, other things being equal, be made proportionately more quickly than a smaller lot. To correct the figures for these influences is impossible, but it is perfectly certain that without the premium system no record approaching that given above could have been made.

The same corporation gave me a second exhibit which was not open to these objections though, unfortunately, it was much smaller. This exhibit showed the results on certain parts which had been reduced to a strictly manufacturing basis. They had been made over and over again and the advantage of sequence was thus eliminated, while the lots were of the same size in both columns of the exhibit. The numbers in the lots of different pieces varied between one hundred and three hundred. Both workmen and foreman were positive that the time on these parts was down to the minimum and that it was useless to apply the premium plan to them. Nevertheless the pieces for which the figures were given showed an average reduction in time of 41 per cent.

Another exhibit of considerable magnitude was supplied by an electrical manufacturing company, the average results shown

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being a reduction in time of 39 per cent., a reduction in wages cost of 28 per cent. and an increase in wages per day of 23 per cent.

These gains are so large as to excite incredulity. Most men of experience will not seriously consider a system which deliberately proposes to increase output by 70 per cent. while reducing wages costs and increasing daily wages by 25 per cent., and I am satisfied that if the plan did about half as well as it really does its growth would be much more rapid than it is. Apart from exact figures, which are difficult to get, is testimony from many men in many lines of work, which is substantially unanimous in saying that the system works in the manner described, and this testimony is not a matter of geography or nationality.

As is the case with all innovations, many and varied objections have been raised to the plan, some based on fundamental or economic and others on more superficial or practical reasons.

Of these perhaps the most fundamental of all is the one which urges that the workman's time, as such, has no value and that it is economically wrong to recognize any value attached to it by a time-rate payment, the argument being that payment by the piece-work system, or its equivalent, is the only method that can be economically sound.

There are two classes of men who take this view of the value of labor—students of economics and employers. A far more numerous class—the workmen themselves—have no sympathy whatever with this view. No one who earns his own living has any other way of measuring the value of his own labor than by the income which it gives him per day, per month or per year. This is true of all grades of men, from the laborer who carries a hod to the president of the United States Steel Corporation, and it is true of all trades, professions and occupations. Ignoring the difference between the employer's and the employee's view of the basis of value in labor leads to an apparent antagonism between the interests of the two classes where in fact none exists. However much we may believe and say that in a general way the interests of employer and employee are identical, we nevertheless tacitly assume and take for granted that in the matter of immediate wages their interests clash. The relations between them are essentially those of buyer and seller, and as the interests of the buyer are with low and those of the seller with high prices, so, it would appear, are the interests of the employer with low and those of the workman with high wages. This is one of

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those half truths which is pretty nearly a whole falsehood, and it is a half truth because in this statement we have ignored or forgotten that the parties measure wages in different units. Stating the case fully, it becomes: The employer's interests are with low wages *per unit of product*, while the workman's interests are with high wages *per unit of time*. There is no necessary antagonism of interest here, and under the premium plan the interests become nearly identical. If an employer, through the payment of increased wages per day, can secure reduced wages per unit of product, it is absolutely clear that the interests of both parties have been advanced. If there is any possible basis of united and co-operative action, this plan would seem to provide such a basis.

A second fundamental objection is made from the standpoint of equity. "These gains," it is said, are "due entirely to the efforts of the workman—how then can you justify an arrangement which gives but a part of the gain to him and gives the remaining and even the larger share to the employer?" Such an objection is based on a very superficial view of the matter. An employer who has erected a factory for the manufacture of a certain article may legitimately ask and expect that that factory shall be operated at its maximum capacity, provided he pays enough in wages to induce his workmen to so operate it. More than this, it must be remembered that under this plan the employer is practically asked to guarantee the continuance of the increased wages, while there is no one to guarantee him even his present scale of prices. The laws of competition hold after the introduction of the system as well as before and these laws forbid that any manufacturer, unless protected by patent or other monopoly, shall make any undue profits. We may be very sure that reduction of costs by this means as well as by any other will be followed by a reduction of prices, and that the employer's gain from the operation of the system will thus become a vanishing quantity. At the last, about the only gain which can be left to him is that due to the increased product from a factory of given size, and perhaps not all of that. Ultimately, the gains due to the operation of the system will be divided between the workman and the purchasing public.

Consideration of this fact, instead of disproving, proves the equity of the division and of the principle given for determining the premium rate. If the premiums are to endure they must be based on the principle laid down—that is, they must be large enough to bring about the desired increase in production, but no larger.

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Antithetical to the objections of the man who would measure the value of labor exclusively by its product are those of the man who argues that the value of every man's labor is fixed in the market and that to pay more than the market rate is simply to dispense gratuities. The man is in a sense right, but his range of vision is limited. It is quite true that every man's labor has a market set price, but that price will only secure his presence in the factory—it will not secure his best efforts. That he shall do his best is not nominated in the bond, and were it so nominated the provision would be unenforceable.

Based on essentially the same foundation is the common objection of workingmen that the premiums are not permanent, but only a temporary affair to be used as a means of showing a man's capabilities and then be removed, while the production obtained under the premiums will still be exacted. This objection was in effect answered above in showing that rate cutting is unprofitable to the employer, but it may be answered more briefly by the statement that the workman is worthy of his hire. All employers pay higher wages to efficient than to inefficient workmen, because compelled to do so. The premium plan simply systematizes this practice and grades, sorts and pays men in accordance with their efficiency, instead of leaving that sorting to general observation and even to favoritism. An employer can no more get the premium output without the premiums than he can get an efficient workman for an inefficient workman's wage.

Finally there comes the man of large experience, who has grown gray in the management of men and of work, and whose knowledge of what constitutes a day's work has become almost intuitive. Such men are safe guides and safe managers, and many of them will say, as some of them have said, that the whole thing is chimerical—that it is a workman's duty to do a whole day's work and a foreman's duty to see that he does it; that a competent foreman can tell if a workman is doing a full day's work or not, and that one who cannot tell is incompetent. Such a man will say, further, that if a workman increases his output under the premium offer it is because he was loafing before and that the last thing to do with such a man is to reward him for his previous loafing by raising his wages. The proper thing to do, according to this objector, is to get better workmen and competent foremen.

It will be seen that this objection is antithetical to and inconsistent with the second one cited. The second objector would

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give all the gains to the workman, while this one would give him none of them.

The fallacy of this man's argument or statement lies in the limitations of his own training and experience. The whole of his accumulated knowledge of what constitutes a day's work is based on a lifetime of experience with methods of payment which offer no incentive to exertion. He has no knowledge of the magnitude of a day's work under incentives, and his appeal to his lifetime of experience is beside the mark. The men who have tried incentives and found them to fail (if there be any such) are entitled to be heard with respect, but the man who has not tried them can, in the nature of things, know nothing about their value. While he is entitled to his opinions like anyone else, his experience has no application and his evidence as a witness or as an expert has no value, and is, in short, "incompetent, irrelevant and unimportant."

Moreover, granting, for the sake of argument, that a workman should do his utmost and that a competent foreman can determine if he does it, the situation is not changed. The real question is: Do workmen do their utmost and can such foremanship talent as is available determine if they do it? The question is to be decided not with reference to what ought to be, but with reference to what is—not with reference to conditions in an ideal world, but to conditions here. We wish an increase of output. Shall we accept human nature as it is and adapt our methods to the conditions which surround us, or shall we spend our time in a vain search for ideal men and ideal foremen, who are so scarce as to be almost nonexistent?

Finally, consider the fundamentally different effect of raising wages in this manner and of raising them in any other whatever. It is the object—and the laudable object—of all labor unions to raise wages. Suppose, for the moment, that all should succeed. The prices of all commodities would be raised in proportion, the increased wages would buy no more than before and the final effect would be nil. No more wealth being produced, the average man would be no better off. Suppose, next, that one union—for example, that of the coal miners—should succeed. The result would be an increase in the selling price of coal and the gain of the miners would be at the expense of all consumers of coal. Suppose, finally, that the premium plan should be applied to coal mining (and it has been applied to metal mining in three cases to my knowledge). The result would be an increase

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in the miners' wages but a reduction in the price of coal. The miners would be better off, but at the expense of no one. They would simply have produced more wealth and have profited accordingly, and instead of injuring consumers, would have benefited them. This sums up the whole philosophy of the system. Through it the production of wealth is increased and in this producers and consumers share alike. If the industrial system of the world is, in a broad sense, simply the co-operative production and distribution of wealth, and if an increase in the total wealth produced, by giving more to divide, increases the amount available for each individual, then the general adoption of the premium plan can do nothing less than advance the prosperity of all.

THE BALANCED COMPOUND LOCOMOTIVE.

H. WADE HIBBARD.

The greatest locomotive works in the world has just celebrated its 70th Anniversary with a banquet at which were gathered two hundred and fifty guests prominent in railroading and allied interests. The completion of twenty thousand locomotives from the time when Matthias W. Baldwin built locomotives contemporaneously with the first railroads, was made memorable, however, by a far more important event than even such a representative gathering of Captains of Transportation. Baldwin locomotive "Number 20.000" will it is believed signalize the date, February 1902, as the successful beginning in America of a type of locomotive destined to have a most profound influence upon railway operation.

The see-saw rivalry between armor plate and guns, khaki and Krag, safes and burglars, dykes and freshets, finds its approximate counterpart in rails and locomotives. Though the magnificent roadbed of the Pennsylvania Railroad is compelled to carry express locomotives having over 25,000 pounds under each separate driving wheel, yet every railway engineer cannot have what a speaker at the New York Railroad Club a fortnight ago called "a billiard table" upon which to operate his motive power. Locomotive weights have very rapidly increased during the past five years, until at the present time the largest give a driving-wheel dead-weight rail pressure of 225,000 pounds. This rail pressure is enormously increased by the necessity for counter-

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balancing the reciprocating parts, as piston and cross-head. These latter, though to-day designed by engineers and of cast steel, have grown so heavy, because of strength needed to transmit the power derived from modern boiler pressure, now reaching 250 pounds by gauge, that in recent locomotives there was not room enough upon the main driving wheel to place the proper counterbalance weight. A *revolving* weight has thus far, in the American type of locomotive, been the only feasible means for balancing the *reciprocating* weight, and its unfortunate but unavoidably attendant vertical effect amounting to several tons upon the rail has been well named the "hammer blow." A full horizontally balanced locomotive has been known, when run at moderately high speeds upon rollers like a bicycle home-trainer, to lift its drivers completely clear of the rollers beneath at a portion of the stroke, coming down again with what would be upon rails a most destructive force. Counterbalancing has therefore been a rather unscientific compromise between either fore-and-aft or up-and-down vibration, out of consideration for the feelings of our railway civil engineering brethren whose rails, rail joints, ties, and bridges, were endeavoring like armor plate to withstand the attacks of our guns.

American pride dislikes to admit that Europe can teach us anything along practical lines. We recognize her present supremacy in art and architecture, music, metric measures and municipal government, and are eager to learn at her feet. But that she could show us better things in money-making engineering, if the bald adjective is allowable, and of all things in Railway Engineering, seems to the intensely commercial American mind an absurdity. Yet military France has flanked the compromise-counterbalance and with "de Glehn" balanced compound locomotives has now taken from the United States the honor of much the speediest long distance heavy express trains in regular service.

It is by the adaptation of the de Glehn to American engineering ideas that the Baldwin Locomotive Works, at its three score years and ten, has celebrated its 20,000th locomotive, the designing skill of Supt. Samuel M. Vauclain and the courage of Supt. of Motive Power, W. E. Symons, combining to place the machine whose photograph appears in the frontispiece,* upon the Plant System of Railways in the south.

* We are indebted to the Baldwin Locomotive Works for the use of this cut.

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To the casual observer, number 20,000 does not seem peculiar. It is a ten wheel heavy passenger or fast freight engine, or 4–6–0, in the new inter-railway nomenclature. The usual outside cylinders are seen, and, in fact, even an engineer standing by her side would have most of his attention called to the Vanderbilt tender which so much resembles an oil tank car. A closer inspection, however, discloses two more connecting rods, in between the frames and under the small portion of the boiler. The front driving axle has lost the universal American straightness and has been given two cranks. Stepping in front of the locomotive, six cylinder heads are seen. Two of these are for the piston valves, and the remaining four are two pairs of high pressure and low pressure cylinders. The low pressure cylinders are "outside connected" to crank pins on the front driving wheels like all American locomotives, and the high pressure cylinders are "inside connected" to the cranked front driving axle of common European type for their usual two-cylindered locomotives. The two high pressure cranks are placed at 90° to each other in order to avoid stalling the engines on dead centres. Each high pressure has its mated low pressure cylinder with crank pin placed at 180° or diametrically opposite the high pressure crank in the cranked axle. By this arrangement a high pressure set of reciprocating parts always has a low pressure set of reciprocating parts moving in exactly an opposite direction, at the same speed, designed to be of the same weight. Practically *perfect counterbalancing* is the result, there being no call to cast counterbalance weights upon the driving wheels.

An incidental result of the combination of no dead centres and perfect balancing is to give four cranks spaced on the four quadrants of the circle. This arrangement, in connection with the long cut-off of a compound, gives a very uniform torque fairly comparable with the electric motor, greatly increasing valuable adhesive coefficient of friction between driving wheel and rail and preventing slipping when starting and accelerating a train or hauling it up a heavy grade. This uniform turning movement and distribution of the stresses on the machine parts diminishes the racking effect, defers repairs, and for years in French experience has made the costs of maintenance of four cylinders as low as two.

Number 20,000 is, as a stationary engineer would say, made up of two engines, each of them compound. The steam distribution to the two cylinders of each compound engine is provided

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for by one piston valve, embodying Mr. Vauclain's patents. This valve has three distinct pistons cast upon the one valve rod. The great experience of the Baldwin Locomotive Works with Mr. Vauclain's very similar piston valve, which is so essential and successful a requisite with the Vauclain four-outside-cylinders adaptation to locomotives of the Woolf Compound, augurs well for the success of the new valve.

The Vauclain–de Glehn locomotive is, as the school-boy would say, without the French "frills": two valves in place of four; four cylinders abreast, instead of two forward inside cylinders connected to one driving axle and two further back outside connected to a second driving axle; our accustomed Stephenson link and valve motion protected from injury under the boiler, instead of the Walschaert link motion, excellent though it is, exposed to blows outside the driving wheels; in short, American simplicity, durability and accessibility, making her an engine to keep at work earning money upon the road instead of idling away her time in frequent and tedious repairs.

A cranked axle is the one part which is un-American. The writer remembers in his boyhood seeing one inside-connected locomotive running upon the Central Vermont Railroad, but the advantages of the outside-connected engine have completely displaced the other. Cranked axles often broke in this country and Europe, and yet the writer was told by different English superintendents of motive power during the summer of 1900, that their breakages in heavy modern service have been eliminated by improved design and forging. The cranked axle for number 20,000 was manufactured "on honor" by the Bethelem Steel Company, guided by their long experience with marine cranks. With so much to commend in this introduction of the balanced locomotive to this country it might seem invidious to criticize, and yet one cannot help wondering why an English railway-made cranked axle was not imported. With all deference to the Bethlehem Steel Company's propeller shafts, the locomotive axle is exposed to radically different stresses. It is not an engine crank and torsion shaft merely, it is not held in rigid marine bearings; but, supporting its carriage load by two independent and free vertically sliding journal boxes, itself has in further difference to hold two driving wheels rigidly together and parallel upon a heaving track and against the leverage of tremendous concussions of flanged tires on often badly curved track and insufficiently elevated outer rail, guiding the whole great mass of perhaps 1500

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horse power boiler plant, engines and carriages around curves laid out for slower speeds. The Baldwin Locomotive Works, even with all its energy and business push, will be unable to prevent the dampening to the new cause which will result if the marine-built axle does not endure railroad service. May it stand up to its work !

The railroad "man on the street" will also wonder that a type of boiler, not yet out of the trial stage, with small grate area too, was placed upon Number 20,000. The radical departure that the Vanderbilt single cylindrical corrugated firebox makes from standard American practice may possibly handicap the interest-earning qualities of the new locomotive. This is the second four-cylindered balanced compound of American build, the other, handicapped in ways not needing mention here, with a novel valve gear and a radically different type of twin cylindrical corrugated firebox, but built by an inventor and not backed by the prestige of unlimited capital, a great locomotive company, and a great railway, lingers in a repair shop after a brief career of which a prominent Superintendent of Motive Power, who had recently tried it, graciously remarked to the writer that "it was a wonderfully smooth riding engine and you could not feel any difference between a bridge and a ballasted track." The Vanderbilt boiler is being hopefully tried by a number of railways, and of course, it is intended to promote rather than retard the success of its latest application.

Number 20,000 is very heavy upon the four leading truck wheels, their 40,500 pounds being wasted in so far as tractive or adhesive weight is concerned. Probably the 127,000 pounds under drivers was all that the Plant rails could endure, or all the adhesion that was needed to develop tractive effort sufficient for the expected train. Later designs calling for more adhesion will doubtless move that rear driver up closer to the middle driver and so adjust more of the weight upon the drivers and relieve the truck wheels. Going still further, the inside cylinders may be placed a little higher and on an incline. This will permit the front driver to be moved forward and close to the cylinders' casting, both cylinders being then connected to the second pair of drivers, the inside connecting rods passing at a slight incline over the front driving axle. Such an arrangement will then allow the reduction of truck wheels to two. A further step may see the lightening of the very heavy cylinders' castings by the substitution of skeleton cast steel, with iron bushings for wear.

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New outside-connected European engines were seen by the writer in 1900 with steel saddle castings uniting the two cylinders and of such combined strength and lightness as to permit the elimination of all truck wheels in freight locomotives. Truckless locomotives, with all weight useful or adhesive, were observed to be driven around the sharp curves of crooked Swiss railways at excellent speed. The Paris-Lyons & Mediterranean Railway has had a number of years' experience with de Glehn freight locomotives of eight drivers and no truck wheels.

Of existing engine 20,000 the most lively anticipations for its future are entertained. Coming as a successful type from abroad, where for several years, on several roads, it has been standard for new equipment, it has been thoroughly Americanized. It is a compound. Itemized reasons for proved success of compound locomotives were given on page 156 of the January number of this *Journal.* Its torque is uniform, with adhesion and hauling capacity per ton on drivers greatly increased thereby, and repairs decreased. But most conspicuously it is totally free from the hammer-blow destructive effect of the common type of impossibly balanced locomotives. It will haul passengers with least vibration, and will be at the same time as easy upon rails as a much lighter machine. In fact it is to be expected that in future the Vauclain balanced locomotives can greatly exceed present allowable wheel weights, making a four-driver locomotive, or 4–4–0, as powerful as a ten-wheeler or 4–6–0. What this means in reduced machinery friction losses and reduced shop and idling expenses, with increased economy of freight and passenger transportation and increased speed, will justify the statement that the Baldwin Locomotive Works and the Plant Railway System have made this year notable by giving their powerful financial and engineering influence to a type of locomotive destined to have a most profound influence upon railway operation in the United States.

Eight new undergraduate scholarships have been established in Lehigh University, five of them being in the engineering departments. These latter are of $150 each, and are allotted among the several courses as follows: civil engineering, mechanical engineering, electrical engineering, mining engineering and metallurgy, and chemistry.

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THE POSITION OF THE UNITED STATES IN THE PRODUCTION AND UTILIZATION OF ELECTRIC POWER.

SIDNEY GRAVES KOON.

That the United States should lead the world in the utilization of electric power for tractive, lighting and general power purposes, is matter for congratulation, though not for surprise; but the extent which our superiority in this respect has now attained is not generally recognized. In Table I is presented a mass of data, part of which was drawn from the February number of the *Engineering Magazine*, which shows pretty clearly the position we now hold; but no tables can ever set forth such a comparison with the distinctness exhibited in a graphical representation of the quantities involved. For purposes of reference, however, Tables II and III are given, the fundamental data for which are contained in Table I.

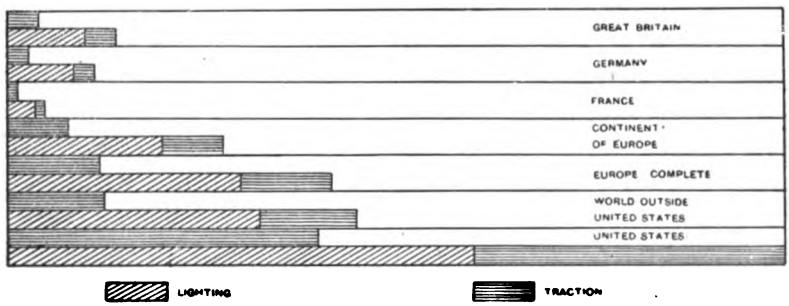

FIG. 1.

Figure I shows the total electrical power available in France, Germany, Great Britain and the United States, as well as in such groups as the European Continent, the Whole of Europe, and the World outside of the United States, at the beginning of the current year. In each instance the portion cross-hatched diagonally represents, to an appropriate scale, the electrical power available for lighting and power purposes, while the horizontally-hatched areas represent the tractive power. The latter are shown separately, in the upper half of the space devoted to each political or geographical division; and again, in the lower half, they are shown, added to the remainder of the electrical

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TABLE I.

	Station Kilowatts			Miles of single track electrically equipped.	Number of motor cars running.	Total capital invested, millions of dollars.	Population.	Area. Sq. miles.
	available for light'g and power.	available for traction.	Total.					
Great Britain,	200,000	80,000	280,000	900	2,600	170	40,000,000	121,115
Germany,	170,000	54,000	224,000	2,300	5,400	140	55,000,000	211,168
France,	70,000	25,000	95,000	800	1,300	58	39,000,000	204,146
Continent of Europe,	400,000	155,000	555,000	5,000	9,800	410	350,000,000	3,756,970
Europe complete,	600,000	235,000	835,000	5,900	12,400	580	390,000,000	3,878,085
World outside U. S.,	650,000	250,000	900,000	6,400	13,500	630	1,420,000,000	46,500,000
United States,	1,200,000	800,000	2,000,000	21,000	68,000	2,900	76,000,000	3,581,885

power, thus giving a ready comparison of the totals. This shows the United States to have more than twice as much electric power available for use as all the rest of the world beside. Indeed, our figures for tractive power alone will closely rival the *total* for the outside world, and are far ahead of Continental Europe. The

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TABLE II.

	Capital Invested		Miles of Track	
	per Capita	per Kilowatt	per 1,000,000 people	per 1,000 sq. mi.
Great Britain	$ 4 25	$ 607 00	22.5	7.44
Germany	2 51	625 00	41.8	10.90
France	1 49	611 00	20.5	3.92
Continent of Europe	1 17	739 00	14.3	1.33
Europe Complete	1 49	695 00	15.1	1.52
World outside United States	0 45	700 00	4.64	0.14
United States	38 18	1450 00	276.2	5.86

TABLE III.

	Total Electrical Power per 1,000,000 people. Kilowatts	Tractive Power in Kilowatts.		Motor Cars per 1,000,000 people
		per car	per mile	
Great Britain	7,000	30.8	88.9	65.0
Germany	4,070	10.0	23.5	98.1
France	2,440	19.2	31.3	33.3
Continent of Europe	1,590	15.8	31.0	28.0
Europe Complete	2,140	19.0	39.8	31.8
World outside United States	640	18.5	38.5	9.6
United States	26,320	11.8	38.1	895.0

backward position of France is cause for comment. Development in that country seems to be very slow. The new plant of the Manhattan Elevated Railway Company, of New York City, which is rapidly approaching completion, will have a power, wholly available for traction, of 40,000 kilowatts, or nearly double the total electrical power available for traction purposes in France, at the present day. The power-house of the New York Edison Company will generate about 55,000 kilowatts, these two together having a capacity just about equal to that found in the whole of France. If we take New York City as a unit, the total power now available, or shortly so to be, will approximate to that at present found in the Empire of Germany. It is only fair to remark, however, that large plants are under construction on the other side, as well as in this country; the 50,000-kilowatt plant in London, mentioned in the February SIBLEY JOURNAL, p. 218, is a notable example. These individual instances are brought forward, not so much to show what is being done in this line at the present time, as to indicate the magnitude which single plants may attain, in comparison with the entire output of some of the most progressive of European nations.

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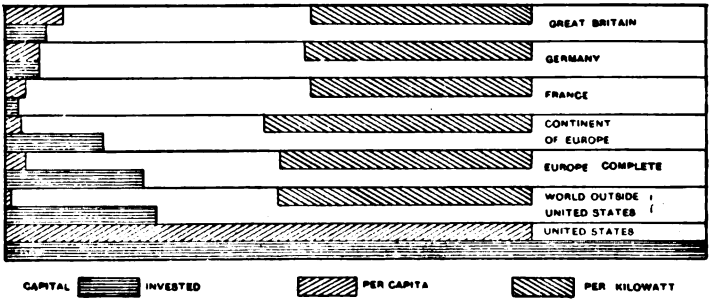

FIG. 2.

Figure II shows the capital invested in the production of electrical power; it also shows the relation which this capital bears to the populations of the various countries; and the "intensity" of capitalization per unit of power output. The capital *per capita*, as shown for the whole world, is a meaningless figure, for there are, of course, included in the population on which it is based, several hundreds of millions of people to whom electrical power is an unheard of and unimaginable entity. For the United States, the capital invested is seen to be nearly five times that of the rest of the world, and fifty times that of France, which has one-half our population. The *per capita* capitalization is here also at a maximum; Great Britain, our nearest rival in this respect, has a figure only one-ninth that which represents us. In the case of the United States, the hatched area representing the capital *per capita* is made to do a double duty, serving also for the capital per kilowatt generated. This latter is seen to be about double the corresponding figures for the other nations,

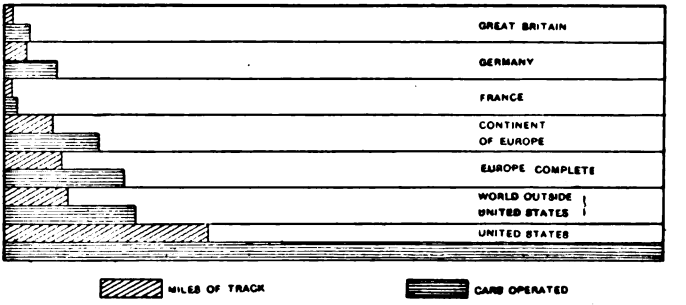

FIG. 3.

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which have each about equal values. This is largely attributable to the higher prices, particularly those for labor, which prevail in the United States.

Figure III shows the number of miles of single track, electrically equipped, and the number of motor cars operated on such track. Our superiority is such as to make comment superfluous.

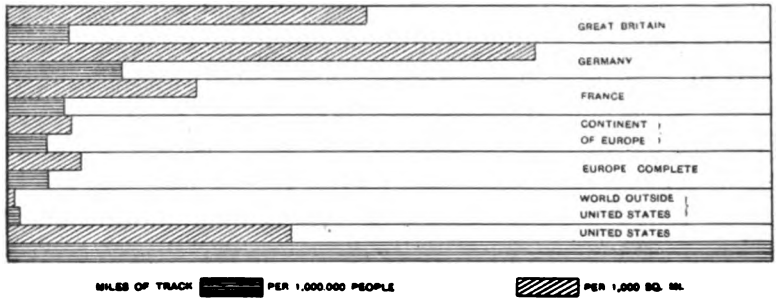

FIG. 4.

Figure IV gives some interesting results. It shows that while, per 1,000,000 people, our trolley track is *far* ahead of that of any other country; yet the restricted areas of Germany and Great Britain, when compared with their dense populations, are sufficiently small to cause their mileage per unit of *area* to exceed ours by a very considerable amount. Our enormous extent of area brings this figure below what other conditions would indicate. The long reaches of the Russian empire exert a similar influence on the mileage per square mile on the European continent. Here, again, the mileage ratios for the world at large have no significance.

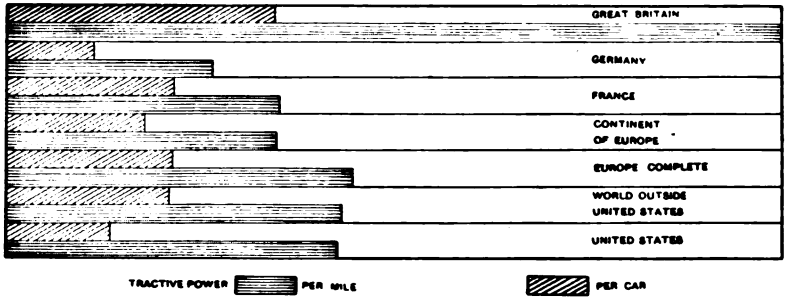

FIG. 5.

Figure V enters into another phase of the subject, and one more in accordance with pure engineering. It shows the amount of power available for traction for every mile of track operated

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by electricity ; and for every car so operated. The extreme density of the population and the short runs made in England would perhaps account, by virtue of the heavy traffic incident to the same, for the great superiority possessed by Great Britain in power output per mile of track. Germany here stands lowest, a fact which would scarcely have been anticipated. As to the power per car operated, Germany is again at the bottom of the list, with the United States next. This is the more surprising when viewed in the light of the now well-recognized fact of the increased economy resulting from the operation of large units, be they steam-engines, or trains, or ships, or even corporations. Yet these two nations are perhaps, from an engineering standpoint, the most progressive on the face of the globe.

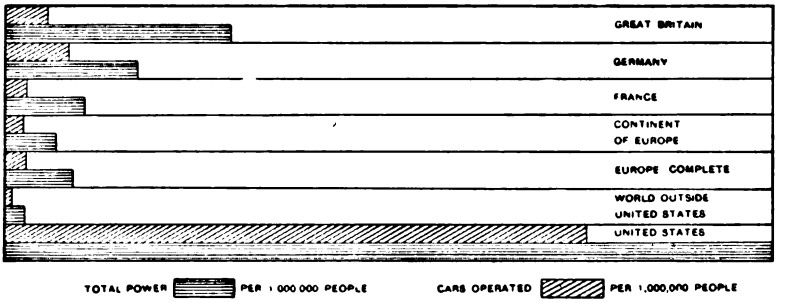

FIG. 6.

Figure VI deals with two quantities : the total available electric power compared with population, and the number of trolley cars operated per million people. Here, as twice before, the figures for the world at large may be ignored, as having no value. The United States has an enormous lead, in both particulars. The relatively low value for the number of motor cars per unit of population in Great Britain may perhaps aid in explaining the preponderance held by that nation in tractive power per car ; the operation of heavy trains of trailers behind each motor car is there common practice.

In conclusion, it is exceedingly gratifying to be able to point to the enormous preponderance of the United States, in every department of this, a great engineering field of the future. We have 69 per cent. of all the electrical power available in the world ; 76 per cent. of all that portion of it available for traction ; 82 per cent. of all the capital invested in the production of electrical power ; 76½ per cent. of all the electric railway mileage ; and 83½ per cent. of all the trolley cars.

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THERMODYNAMICS OF THE GAS-ENGINE.

The second report of the Gas Engine Committee of the Institution of Mechanical Engineers of Great Britain was presented on the 18th of October by Professor Burstall, of Birmingham University, and the results of experiments, preparations for which were described in the first report (*Proceedings*, 1898) were given. They involve some important details of a novel character and throw some light upon previously obscure points in the theory of that now important prime mover.

Illuminating gas was employed, having a mean heating value of about 4.8 calories per liter. A new form of igniting apparatus permitted the ignition of even very weak charges with completeness and certainty, the current being obtained from four cells of the storage battery, with a low voltage and a comparatively heavy current, insuring a 'short and thick' spark.

Varying compression was adopted to determine the effect of such variation upon the efficiency of the motor, and, with each compression, varying mixtures of air and gas, changing about one per cent. at each new series of tests, supplied data for ascertaining the relative values of these mixtures.

For the first time, so far as the writer is aware, the theory of the gas-engine as here applied was constructed with the assumption of a variation of specific heats with temperature, following MM. Mallard and Le Chatelier. The following are Professor Burstall's formulas:

$$K_v = a + sT; \qquad K_p = b + sT;$$

$$K_p - K_v = \text{const.} = b - a = R.$$

$$H_v = (w_1 + w_2) \int_{T_1}^{T_2} (a + sT)\, \delta T;$$

$$= (w_1 + w_2) [a(T_2 - T_1) + s/2 \cdot (T_2^2 - T_1^2)];$$

$$H_p = (w_1 + w_2) \int_{T_2}^{T_3} (b + sT)\, \delta T;$$

$$= (w_1 + w_2) [b(T_3 - T_2) + s/2 \cdot (T_3^2 - T_2^2)];$$

where H_v and H_p are the quantities of heat added during the periods of constant volume and constant pressure, respectively; w_1 and w_2 are the weights of air and gas, and the weight of residual products from the previous stroke in the clearance spaces.

The equation of the adiabatic also differs from that for constant values of specific heats, thus:

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$$\delta q = K_v\left(\frac{dT}{dp}\right)\delta p + K_p\left(\frac{dT}{dv}\right)\delta v;$$

$$dT/dp = v/R;\ dT/dv = p/R:$$

$$\delta q = K_v v/R\cdot\delta p + K_p p/R\cdot\delta v = 0.$$

$$(a + sT)\,vdp + (b + sT)\,pdv = 0.$$

$$(b - a)\log_e v + a\log_e(pv) + spv/R = \text{const.}$$

$$p^a v^b e^s \frac{pv}{R} = \text{const.}$$

The correspondence of the actual expansion lines of the indicator diagram with the adiabatic for variable specific heats was found much closer than for the usual assumption of constant values with varying temperatures. In the computations of the heat-balance the usual method would give results about fifteen per cent. lower than with variable specific heats.

The entropy equation becomes, in the latter case,

$$\phi = a\log_e\frac{T}{T_0} + R\log_e\frac{V}{V_0} + S(T - T_0);$$

where V and V_0 are the volumes at temperatures T and T_0, respectively.

In determining the temperatures, the Callender platinum instrument was employed; but a peculiar and ingenius special construction was adopted to secure safety of the instrument against injury by the action of the charge. Among other interesting determinations made with this thermometer, were the temperatures of the charge at various distances from the cylinder-wall. It was found that the charge was distinctly hotter at the core than adjacent to the metallic surface of the cylinder, the difference ranging from one to two hundred degrees centigrade.

The gas used required 5.49 volumes of air for combustion and produced 0.5672 volumes of CO_2 and 1.257 volumes of steam. After combustion the volume is, total dry, 4,996. The weights were, gas, per meter, 0.6; air, 1.29. Heating values were 553 B. T. U. per cubic foot, 4,850 calories per cubic meter.

The engine was six inches by twelve and ran at about 200 revolutions per minute and at from 90 to 100 per cent. of its rated power, usually at about 95. The compression in Series I. ranged up to from 200° C. to 300° C., and the index of the compression-curve, $pv^n = C$, from 1.28 to 1.445, its maximum being found at 311° C.; but the irregularities of the figure are too great to reveal any law. Probably 1.33 may be taken as the figure for approximate computations. The expansion-curve value of $n = 1.4$, as an

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average, or very nearly that, ranging from 1.328 to 1.501. The mechanical efficiency was from 68 to 80 per cent., averaging about 75.

In the final series of trials, with compression ranging from 327° C. to 452° C. as maxima, the index of the expansion-curve was about 1.3, varying from 1.2 with an exhaust temperature of 637° C. to 1.344 with a temperature of exhaust of 862° C. The compression curve was less variable; the index averaged very nearly 1.35. The mechanical efficiency varied from 0.64 to 0.83; and the thermal efficiency from 18.1 to 22.7 per cent.

The employment of compression produced, on the whole, an increasing total efficiency with increasing terminal pressure, though reducing mechanical while augmenting thermodynamic efficiency. From 13 to 16 per cent. of the heat-supply appeared as useful work outside the machine. The gas used ranged from an average of 24.6 cu. ft. per I.H.P. per hour to 19.7, and from 34.9 per B.H.P. to 28.5. The jacket carried away about 30 per cent. of the heat developed, the exhaust about 45 per cent. and radiation about 3. The heat-balance for the most efficient case was

I.H.P.	JACK.	EXH.	RAD. LOSS	TOTAL.
23.1	+ 30	+ 42.6	+ 3 + 1.3	= 100.

R. H. THURSTON in *Science*.

RECENT EXPERIENCE AND TESTS WITH WASTE HEAT ENGINES.

A publication bearing the above title, by Professor E. Josse, gives an interesting account of experiments made by him in the laboratory of the Royal Technical High School, of Berlin, together with descriptions of two commercial engines which have been installed to utilize the exhaust waste of steam engines.

A company has been organized to develop this form of binary vapor engine. One waste heat engine of 60 or 70 horse-power has been in operation for a year and a half and an engine of 175 horse-power, running in conjunction with a steam engine of 360 horse-power, was completed in May last.

The thermodynamic principle involved in the operation of these latest binary vapor engines is not at all novel; they are of particular interest because of the exceedingly thorough manner in which the commercial adaptation is carried out.

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As a preliminary to a brief explanation of operation of the engine, it may be well to state certain properties of the working fluids which are employed. These fluids are water vapor, or steam, and sulphur dioxide. The temperature of steam at an absolute pressure of 3 pounds per square inch (which corresponds to a vacuum of about 24 inches) is approximately 142° Fahr. A saturated vapor of sulphur dioxide at this temperature corresponds to an absolute pressure of nearly 160 pounds per square inch. The pressure of SO_2 vapor at 60° Fahr. is about 41 pounds per square inch. It thus appears that if SO_2 can be raised to the temperature of the exhaust steam of a condensing engine (say 140° F.) and, after working through an engine, be condensed under the temperature of 60° F., there will be a working range of pressure of nearly 120 pounds per square inch. The attainable range is somewhat less, but it is sufficiently great to be utilized.

In this waste heat engine, SO_2 is used as the cooling fluid in the surface condenser of the steam engine. Cold liquid SO_2 is pumped into the tubes of this condenser, while the exhaust from a steam engine enters the shell containing these tubes. The transfer of heat from the exhaust steam to the SO_2 causes the former to be condensed, while the latter is vaporized. It is thus seen that this condenser performs the double function of condenser for the primary (steam) engine and boiler for a secondary (sulphur dioxide) engine. After the SO_2 vapor has been worked through the secondary, or waste heat engine, it is condensed in a surface condenser which is supplied with cooling water at the natural temperature.

Of course, the temperature of the SO_2 cannot be raised to that of the exhaust steam in the condenser-vaporizer; neither can it be cooled to the temperature of the water supply; but by providing sufficient cooling surface in the two condensers, the discrepancies are not so large as to frustrate the effort to obtain considerable energy from the waste heat engine. Some comparisons of the cooling surface of these condensers with the surface required in condensers of ordinary steam engines will be made in a later portion of this paper.

The essential elements of the binary vapor plant are a boiler for generation of steam, a steam engine through which this steam is worked, a condenser-vaporizer in which the exhaust steam is condensed and the sulphur dioxide vapor is generated, a waste heat engine in which this secondary vapor is worked, and a con-

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denser for this last vapor in which it is condensed and cooled preparatory to again entering the first condenser as the cooling fluid. In addition to these elements auxiliary pumps are required. There must be an air pump to remove the air and condensed steam from the first surface condenser; also a pump, or pumps, for removing the condensed SO_2 vapor from the second condenser and forcing the liquid into the tubes of the first condenser.

Much labor and ingenuity has been expended in attaining satisfactory details of the design, but all reference to the construction of these elements must be omitted from the present paper. It is asserted that the almost innumerable "practical" obstacles have been successfully overcome.

Thirteen distinct tests on the experimental plant are reported; twelve with superheated steam and one with saturated steam. Nine tests were with a triple expansion steam engine, and four with the engine run as a two cylinder compound. One test was run at half load and one "with small quantity of circulating water."

It is evident that a steam engine of high economy affords less opportunity for waste heat utilization than does an engine of larger steam consumption, because the latter has a greater waste to be utilized. The most striking feature of the tests reported by Professor Josse is that with the triple expansion engine using superheated steam, the waste heat engine developed from 30.5 per cent. to 40 per cent of the power developed by the steam engine. In these particular tests, the steam consumption of the triple expansion engine ranged from 11.2 to 14.4 lbs. per I. H. P. per hour.

With the compound steam engine, and a water rate ranging from 13.4 to 14.5 lbs. per I. H. P. per hour of the steam engine, the waste heat engine developed from 34.6 per cent to 39.4 per cent. of the steam engine output. With dry and saturated steam (triple engine) the water rate of the steam engine was 16.4 lbs. per I. H. P. per hour, and the output of the waste heat engine was 42.1 per cent of the power of the steam engine.

The average results from seven of the trials with the triple expansion engine using highly superheated steam were as follows:

Triple Expansion Steam Engine, I. H. P. =	146.4
Steam Consumption per I. H. P. hour =	12.8
Waste Heat Engine, I. H. P.,	52.7
Percentage Power of Waste Heat Engine	35.9
Consumption of Steam per I. H. P. of Combined Engine	9.43

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Two important considerations which suggest themselves are the quantity of water required in the SO_2 condenser and the amount of cooling surfaces necessary in the condensers.

In regard to the matter of cooling water, Professor Josse says: "The quantity of heat in the condenser of the waste heat engine to be carried off by the cooling water is smaller than is the case in the condenser of the steam engine portion, for a portion of the waste heat of the steam engine is transformed into work in the waste heat engine. Furthermore, in comparing the circulating water consumption, a steam engine should be chosen of a capacity corresponding to that of the combined steam and waste heat engine."

During the test, the circulating water "underwent an increase of about 13°, from about 50° at the inlet to about 63° at the outlet. The circulating water consumption for the combined machine amounted to about 55 gallons per indicated horse power hour. For a steam engine the circulating water consumption amounts to about 40 gallons, or one-third less.

"Now it is at once apparent that with the low temperature-increase of the circulating water during the tests, a few degrees more or less, while greatly influencing the amount of circulating water required, has but very slight effect upon the performance of the SO_2 engine. Consequently, if for the circulating water of the waste heat engine one permits a temperature-increase of say 18°, the circulating water consumption will not be higher than in steam engines."

In regard to the amount of cooling surface, it is said by the investigator that "for the machines of the Technical High School the surfaces of the vaporizer and of the condenser were very liberally proportioned out of regard for the tests to be made. The tests showed that—in general—the transmission of heat energy in the vaporizer takes place much more readily and with less loss than in the condenser. This favorable result may be attributed to the fact that the transmission of heat energy takes place here at higher temperature, and also to the circumstance that molecular changes are occurring on both sides of the heat-transmitting surfaces.

"The results lead to the deduction that there should be provided for the vaporizer a surface of from 5 to 7.5 square feet per I. H. P., and for the condenser from 20 to 25 square feet per I. H. P. For these dimensions, however, a special construction of the surface apparatus is presupposed, by virtue of which one achieves

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this relatively higher specific rate of transmission of thermal energy."

By way of comparison, it may be stated that an ordinary condensing engine requires only one instead of the two surface condensers, and that, with the usual temperature increase of about 60° in the circulating water, from 1.5 to 3 square feet of cooling surface per I. H. P. is sufficient.

Notwithstanding the cost of extra condensers, and the possible excess of cooling water demanded, if the waste heat engine can, in commercial operation, develop one-third of the power of a high grade steam engine on the waste heat of the latter, that is with no additional fuel cost, it certainly has a favorable chance of survival.

JOHN H. BARR.

A RADIATOR TEST WITH SUPERHEATED STEAM.

H. F. MOORE AND E. SCHLEMMER, JR.

Some years ago in testing a steam radiator in Sibley College, superheated steam was by mistake admitted to the radiator. The run in progress was completed, and when the results were computed it was found, contrary to expectation, that the heat transmitted by the radiator per hour per degree difference of temperature between entering steam and temperature of room was diminished rather than increased. Prof. Carpenter, noting the peculiarity of this result, decided to investigate the matter further and at his request Mr. C. D. Gray undertook the work and made a series of experiments, the results of which were published by Prof. Carpenter and attracted considerable attention. At his suggestion the writers of this article have undertaken to verify the results referred to and to determine experimentally the heating value in a radiator, of superheated steam. This article gives the data and results of the latter experiment.

The object of the experiment was to ascertain for a number of different degrees of superheat in the entering steam the B.T.U. transmitted through a radiator per hour per degree difference between entering steam and room. A secondary object of the experiment was to find the difference in the readings of two thermometers, one in a thermometer cup extending inside the radiator and the other placed against the outside surface of the radiator.

The method employed was to measure the heat supplied to the

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radiator and that rejected from the radiator. The difference between these two quantities is the heat transmitted by radiation and convection from the radiator.

The apparatus employed is virtually that described in the chapter on testing of heat transmitted from radiating surfaces in Prof. Carpenter's "Heating and Ventilation," with the addition of a superheating device, and is illustrated in the accompanying sketch.

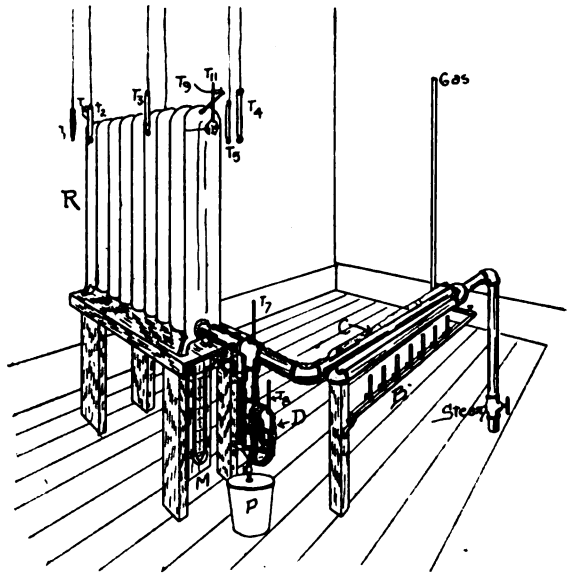

FIG. 1.

Low pressure steam from the University heating mains was passed through the coil *C* to the radiator *R*. Under the coil were placed a row of Bunsen burners by means of which the steam could be superheated any desired amount. The radiator used had a single pipe connection and was manufactured by the J. L. Mott Iron Works.

The condensed steam drained into the drip pipe *D* which was fitted with a gauge glass. From the drip pipe it was allowed to flow into the bucket *P* at such a rate that the water level in the drip pipe remained constant. Thermometers T_1, T_2, T_3, T_4, T_5 and T_6 measured the temperature of the room. T_7 measured the temperature of the incoming steam and was placed as near the radiator as the piping would allow. T_9 and T_{10} measured the temperature of steam in the upper portion of the radiator at the

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steam end and the air end. T_{11} was placed against the surface of the radiator and carefully lagged with hair felt; and T_8 was placed in the condensed steam of the drip pipe. A manometer M measured the pressure of the incoming steam. The drip pipe and the steam pipe from C to the radiator were carefully lagged with hair felt.

If D be the degree of superheat of the entering steam, as determined by T, and the manometer reading, W the pounds of steam condensed in a run, λ the total heat above 32° in a pound of dry and saturated steam of the pressure shown by the manometer, q the heat in water of the same temperature as dry and saturated steam of the above pressure, then, if H equals the total heat supplied per pound of steam

$$H = \lambda + C_p D$$

where C_p is the specific heat at constant pressure of steam for which we may use Regnault's value of .4805.

The heat rejected per pound of steam (H') is

$$H' = q$$

$(H - H')W$ equals the total heat radiated during the run, from which, knowing the length of run, the difference of temperature between entering steam and air of room, and the area of our radiating surface we can compute the B.T.U. transmitted per hour per degree difference of temperature between entering steam and air of room per square foot of radiating surface.

Following are the results of six of the eight runs made; also a curve showing the relation of transmitted heat capacity and degree of superheat.

Run Number.	1	3	5	6	7	8
Barometer	29.59	29.32	29.09	29.52	29.09	29.10
Temperature:						
Room	86.75	87.60	91.46	91.80	87.90	96.0
Entering steam	216.3	248.4	277.4	307.7	326.0	346.2
Condensed steam	216.3	218.8	221.4	219.8	221.1	221.9
Inside radiator	211.1	213.2	213.2	217.0	218.6	219.1
Outside radiator	207.5	208.3	209.6	213.6	213.7	213.2
Difference	3.61	4.94	3.59	3.4	4.34	5.6
Steam press., absolute	16.01	16.8	17.65	17.14	17.56	17.85
Degree of superheat	0	29.6	56.0	87.9	104 9	124.3
Total heat per lb.	1119.1	1162.8	1176.3	1191.0	1199.5	1209.1
Same, condensed	184.9	187.5	190.1	188.5	189.8	190.7
Heat radiated per lb.	934.2	975.3	986.2	1002.5	1009.7	1018.4
Steam condsd. per hr.	5.77	5.72	5.65	5.28	5.72	5.33
Total heat radiated	5390	5580	5585	5295	5760	5432
Same, per hr. per. deg.	41.55	34.74	30.0	24.5	24.22	21.7
Same, per sq. foot of surface	1.405	1.173	1.014	.827	.819	.734

Surface of radiator = 29.60 square feet.

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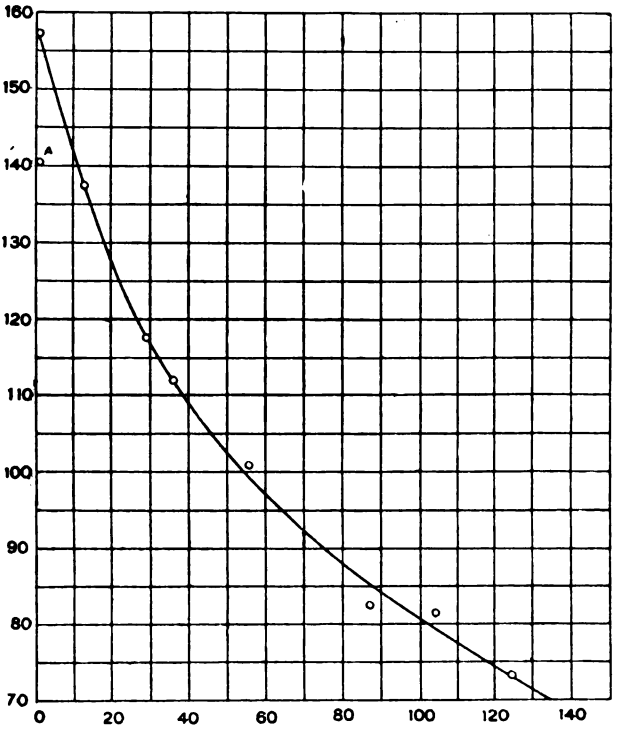
The results show plainly the falling off in heat transmitting capacity as the degree of superheat is increased. The curve, however, becomes flatter with increased superheat, showing that the rate of decrease diminishes with increase in amount of superheat. It will be noted that, with a slight degree of superheat not only did the heat transmission decrease per degree difference



A—Steam three per cent. wet.

FIG. 2.

of temperature, but the total heat transmitted per hour decreased, showing plainly the decreased heating value of superheated steam. Of course, this decreased heating value makes superheated steam all the more valuable for power transmission purposes, as heat radiated in such cases is heat wasted.

The temperatures inside the upper portion of the radiator are seen to be lower than the temperature of dry and saturated steam of the pressure shown by the manometer. This would seem to indicate that, in spite of the precautions taken, some air was in the radiator during the test. The usual means of avoiding this

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were employed, steam being allowed to blow through the radiator for three quarters of an hour before the beginning of a run, and the air valve being tested every ten minutes.

The reason for the decreased heat transmitting power of superheated steam is doubtless to be found in the fact that it is a more nearly perfect gas than wet, or dry and saturated steam, and, in common with other gases, has poor heat conductivity and therefore does not part with its heat so readily as does a vapor.

There seemed to be throughout all the runs a difference of three or four degrees Fahrenheit in the readings of the thermometers placed on the inside and the outside of the radiator. This difference was rather irregular and probably some air currents crept under the lagging of the surface thermometer. This difference is probably due to loss of heat by the external thermometer in contact with the radiator surface.

It is to be noted that the experiment does not show what results would be obtained with superheated steam *in* the radiator as it will be noted that the only steam which was superheated was that entering. Further experiments will be made relating to the effect of superheated steam in the radiator itself. The experiment does show the loss of efficiency of a radiator when supplied with superheated steam.

A Cornell man's record:—"While with the Winchester Company, of New Haven, Conn., I was able to command machinist's pay working at that trade. I have letters from President Bennett and other officials of this Company expressive of their regard for services rendered. For the Edison Light & Power Company, of Easton, Pa., I completed a map of the territory covered by their system of electric lighting, illustrating the extent and location of various lines and the number and size of feeders on every pole within this territory. During my present employ I have supervised wiring contracts of Sayre and Wilkesbarre shops; furnished plans for electric lighting of Easton shops; have installed engines and dynamos belted and direct connected, of sizes varying fram 30 H.P. to 175 H.P. and motors from 5 H.P. to 60 H.P. Have operated successfully a plant carrying 1200 incandescent lamps, 150 arc lamps and motors with a total capacity of 200 H.P., and am familiar with the details of such work both inside and outside the power house."

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THE SIBLEY JOURNAL OF ENGINEERING,
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WE desire to obtain a few copies of the SIBLEY JOURNAL, for the months of October and November, 1898, June, November and December, 1899, March, 1900, and January, 1901. Cash will be paid for these upon presentation to either the Business Manager or the Editor-in-Chief.

SEVERAL of our contemporaries have recently been enlarging, editorially or otherwise, upon the advantages to the engineer of a systematic compilation of notes and references in the form of a card index, from which he may, when necessary, abstract either the information immediately required, or determine where he can most readily obtain that information. We are gratified to note that, in every case which has come to our attention, the basis of the argument has rested upon the lecture delivered by

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Professor H. Wade Hibbard before the *Cornell Society of Mechanical Engineers*, in the fall of 1900, and published in the SIBLEY JOURNAL for December of that year, and later in the *Proceedings* of the Society for the year 1900–01, and also in the form of a separate pamphlet.

Department Notes.

Mr. D. L. Cease, the editor of the *Railroad Trainmen's Journal*, who was expected to come to Cornell at an early date to discuss the principles of organization and administration of the industries, but whose visit has been deferred, writes the Director of Sibley College that the "Brotherhood" has about 50,000 members, has $600,000 in bank, and has made its success by reversing the too common order of things and endeavoring to work in harmony with the employers, rather than the contrary; representing "in the fullest degree the application of the plan of collective bargaining where the terms of the compact are strictly observed by the labor organization." This is regarded as an ideal "modern and progressive labor organization."

Personals.

'88. W. B. Smith Whaley, M.E., is the author of an interesting and well-illustrated article in the current number of *Cassier's Magazine*, on "Electric Power in American Cotton Mills". While thus made national in its scope, the article is largely confined to a description of the plants within the author's own chosen field of operations—the south; and, more particularly, South Carolina. Having himself done perhaps more than any other man to develop this growing industry of the south, and place it upon a firm scientific and engineering basis, it is but natural that his main attention should be devoted to the mills which have been organized and equipped under his immediate supervision. These having been described briefly in the SIBLEY JOURNAL, of February, 1901, pages 221 and 222, we will add merely a few details not there noted. The "prime mover" furnishing power for the electric drive consists of three 2000-H.P. vertical cross-compound engines, built by McIntosh, Seymour & Co., of Auburn, N. Y. These are direct connected to three

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generators of the revolving field type, which, in turn, drive the motors placed where needed about the mills.

Among the advantages claimed for this system of power installation may be quoted: "I, Less costly and more conveniently arranged buildings; II, immunity from interruptions due to the necessity of shutting down the whole plant on account of any section's being out of order; III, more economical steam plants, both in first cost and in operation; IV, a very large saving in shafting and belting; and V, the absolute unimportance of the relative position of the power plant and the mill." The saving in friction alone is estimated at 20 per cent., while "the producing capacity of the machinery operated is, in actual practice, increased about 4 per cent., due to the steadiness of this method of driving over the usual method of ropes and belts."

'89. Bion Joseph Arnold, E.E., is the subject of a four-page biographical sketch in the current number of *Cassier's Magazine*, the frontispiece of which is his portrait. "On leaving Cornell, he engaged with the Thomson-Houston Electric Co., taking charge of the St. Louis office as engineer and agent. Two years later he was appointed consulting engineer for the Chicago office of the same company, a position which he continued to hold after the consolidation of the Thomson-Houston and Edison General Electric companies into the General Electric Company. He next established himself as an independent consulting electrical engineer, and since 1893, has devoted his attention to the design and construction of many electric properties throughout the United States and Mexico, to perfecting inventions and improvements which have given him additional reputation. International reputation was gained by him as designer and builder of the Intramural Railway power plant at the World's Fair at Chicago, in 1893, which embodied many new ideas and may be said to have formed the basis for subsequent practice in this direction."

'92. John Sedgwick Peck, E.E., forms the subject of a sketch in *Electrical World and Engineer*, in the series of "Electrical Engineers of the Day," published in that journal. After a few months' work in the shops and drafting room of the Eddy Electric Co., of Hartford, Conn., Mr. Peck entered the employment of the Westinghouse Electric and Manufacturing Co., at Pittsburg, in the spring of 1893. Here he worked his way through the shops, testing department, and laboratory, finally taking up the design of transformers, in which he has been markedly successful. He is a member of the American Institute of Electrical Engineers.

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'95. Clayton H. Sharp, Ph.D., formerly instructor in the Dynamo Laboratory and in the Physics Department, presented before the American Institute of Electrical Engineers, on January 3rd, 1902, a brief paper under the title: "The Present Status of the Question of a Standard of Light."

'99. A. G. Rakestraw, E.E., now with the Westinghouse Electric & Manufacturing Co., of Pittsburg, writes us as follows: "About eighty of the Westinghouse apprentices and ex-apprentices gathered around the festive board at the Hotel Duquesne, Pittsburg, on the evening of Washington's birthday, at their first annual dinner. Several of the officials were present, and gave friendly talks to the men about their work and opportunities. The object of the event was well accomplished, namely, to promote feelings of fellowship and harmony among the 'students', and to bring about a closer relationship and a better understanding between them and the management. The intention is to repeat the affair annually, and to endeavor to inaugurate new features, which will prove of benefit to the men." A very considerable number of these apprentices are Sibley College graduates.

Mr. Gardner F. Williams, an American engineer, has been for many years the General Manager of the great DeBeers Consolidated Diamond Mines in which Cecil Rhodes has an important interest and from which he has drawn a handsome part of his great fortune. Mr. Charles Henrotin (M.E., '97) is on the staff. Mr. Alpheus F. Williams, a son of the Manager and formerly a Sibley College student, is now made Assistant Manager and has been Acting Manager during the absence of the General Manager in this country. Mr. Percy A. Robbins (M.E., '94) is Mechanical and Electrical Engineer. The annual report of the Manager and Directors is now distributed and it is shown that that organization produced last year over $20,000,000 worth of diamonds at a net profit of about $10,000,000, and, including returns on other properties and investments, nearly $15,000,000. The Boer war has not apparently caused any business embarrassment since the relief of Kimberly, except in making labor more costly. As in this country, however, a scarcity of railway cars has made transportation a troublesome problem. The methods of working are largely American, the machinery in considerable proportion also. Many young Americans, including several Cornellians, are here employed. The dividends paid are usually *forty per cent. per annum* on the capitalization, which is in round numbers and in United States denominations, $20,000,000.

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BOOK REVIEWS.

L'Électricité à l'Exposition de 1900, published with the assistance and under the technical direction of Mm. E. Hospitalier and J.-A. Montpelier, with the aid of engineers and industrial electricians, Vve Ch. Dunod, publisher, 49, Quai de Grands-Augustins, Paris, 1901. Price of the entire collection, which comprises some 15 numbers, 50 francs.

The fourth number (ninth in the order of appearance) : "Transformation of Electrical Energy" : I.—Instantaneous Transformers, by E. Hospitalier. II.—Accumulators, by A. Bainville. 93 large pages, with 119 figures.

In part I are discussed and illustrated various types of rotary converters and static transformers. These are designed for single, quarter, and three phase systems of transmission. A number of sections and wiring-diagrams aid in the reading, while curves of performance serve to give some idea as to what results may be expected. Part II, after reviewing the general field of accumulators, or storage cells, introduces type after type of storage batteries, mostly of the conventional lead-gridiron style, emanating from both Europe and the United States, and closes with a description of a few cadmium and gas accumulators.

OUTLINES OF ELECTROCHEMISTRY. By HARRY C. JONES, Associate Professor of Physical Chemistry, Johns Hopkins University. New York : The *Electrical Review* Publishing Co., and D. Van Nostrand Co., 1901. Price $1.50. Pp. vi + 106. 13 illustrations.

This little book consists of a series of papers published in the *Electrical Review*, and now collected into one volume. While not a complete treatise on the subject, the most important phases of electro-chemistry are presented. The book opens with a consideration of the phenomena of osmotic pressure, and the relations between this peculiar form of molecular action and gas-pressure. The theory of electrolytic dissociation calls for extended treatment, and is followed by a chapter devoted to its applications. Electrolysis is discussed in the light of the various theories which have successively been held to account for it. The velocity of ions forms the subject of a number of experimental determinations. The conductivity of solutions is accorded an extensive treatment, followed by a discussion on the electro-motive force of elements, with calculations.

In the analytical discussions, free use has been made of the calculus, whenever it appeared convenient to employ it ; and throughout the book exact and thorough methods have been adopted. A number of references to other works adds to the value of the volume.

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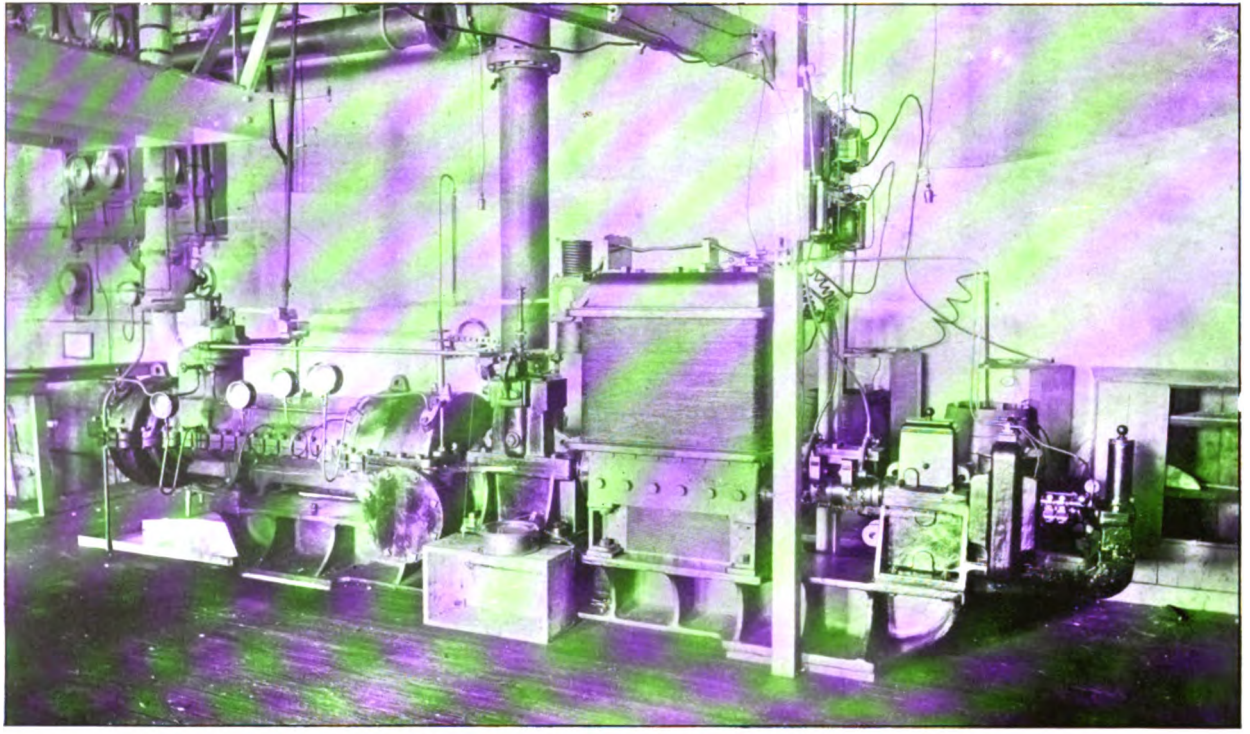

THE SIBLEY COLLEGE PARSONS STEAM TURBINE.

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THE SIBLEY JOURNAL OF ENGINEERING.

VOL. XVI. APRIL, 1902. No. 7.

IN CORNELL UNIVERSITY.

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislature of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

EVOLUTION OF THE SHAFT GOVERNOR.*

R. C. CARPENTER.

The development of the shaft governor has been a slow and steady one in this country, commencing probably in 1829, or possibly even later. It is quite probable that for a long time this governor met with little or no practical application, as it is a fact which will appear later that the period of its practical application can hardly be said to have begun before 1876. Since that time the growth in use of this governor in this country has been remarkable and many forms have been produced, all of which possess more or less merit. In England this governor seems to be scarcely known to-day, judging at least from the literature on the subject, while on the continent of Europe its use is also very limited.

My sources of information regarding the development of the shaft governor are principally to be found in the literature relating to the steam engine, which has been published from time

*Paper read at the meeting of the Engine Builders' Association, New York, December, 1901. We are indebted to the courtesy of *Power* for the illustrations accompanying this paper.

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to time during the last thirty or forty years, and in the records of the United States patent office.

The general works relating to the steam engine, with the exception of a few American works in late years, contain very little in relation to the shaft governor. So far as I can ascertain, all the works published by English authors, even up to a very late date, are entirely silent on this subject; thus, for instance, the work on the steam engine by Prof. John Perry, written in 1899, while devoting a full chapter to the subject of the fly wheel and governor, and while describing in full the theory and various forms of the pendulum governor, is absolutely silent regarding the shaft governor. So far as I can learn from the literature which has been printed in England regarding the steam engine any student obtaining his information from such books would know nothing whatever of the structure of the shaft governor.

The French writers on the subject do give considerable information relating to the subject of the shaft governor; the governor is, however, invariably described as an American invention which is used on certain American engines and one obtains the idea from such a description that the governor is little used in France.

American books relating to the structure of the steam engine published twenty-five years ago entirely neglect the existence of such a governing device, and it seems quite probable that although the shaft governor was used twenty-five years ago to a very limited extent, it had not, at that time, made a sufficiently strong impression on writers to lead them to consider that it was a practical device. As illustrations of this kind, we note a few instances. Thus, Knight's Mechanical Dictionary, published in 1877, is a work devoted to explaining the structure of various machines and prime movers, and has never been surpassed or even equaled in its particular field. This work describes in detail the structure of a large number of governing devices and presents a full-page illustration showing the forms of governors supposed to be of practical value. (Fig. 1.) You will notice that some twenty-three different forms are shown, all, however, of the type known as the rotating or swinging pendulum governors, and none belong to the class which it is the object of my paper to describe. In Appleton's Encyclopædia of Applied Mechanics, published in 1878, and edited by the ablest corps of specialists ever employed at that date in this country, is a very full and complete article on the steam engine, but it

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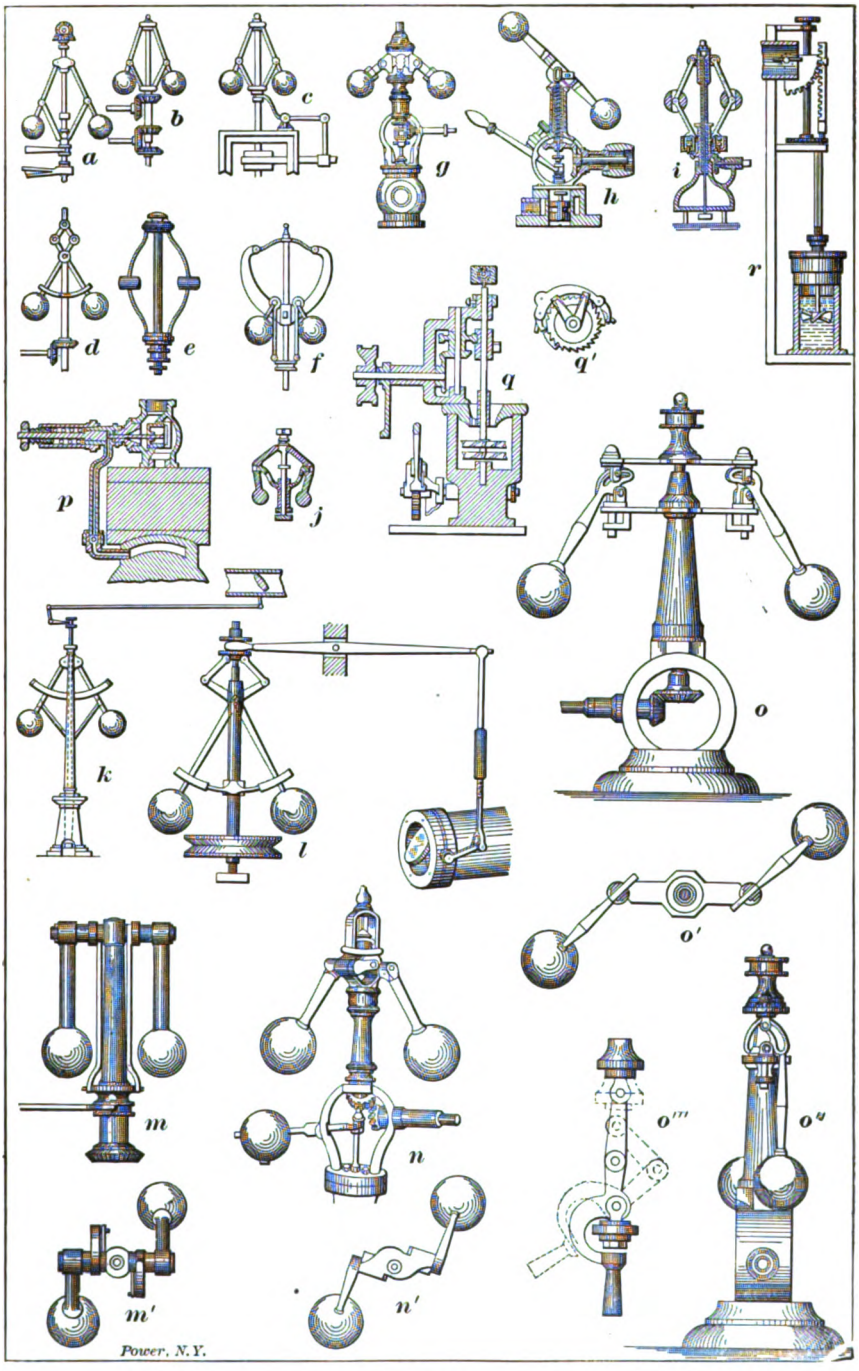

FIG. 1.

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makes no reference whatever to the use of the shaft governor, which was perhaps inexcusable at that date, as a shaft governor was exhibited at the Centennial Exposition in 1876.

The oldest book which I have in my library containing references to the shaft governor is "Steam Using; or, Steam Engine Practice," written by Prof. Charles A. Smith, of St. Louis, in 1885. In this work are published detailed drawings of a Westinghouse engine, and also a Buckeye engine, and each is shown with a shaft governor. I have no information at hand which enables me to state the earliest dates at which these companies commenced the building of shaft governors on a commercial scale, nor am I certain but that other engine companies introduced the use of the governor at a somewhat earlier date. Views of these governors as given in Prof. Smith's work are shown in

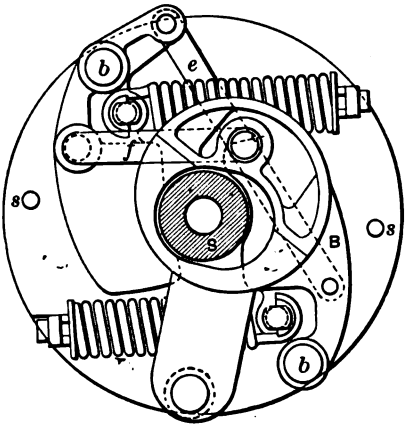

FIG. 2.

Figs. 2 and 3. At the Centennial Exposition at Philadelphia, held in 1876, Prof. John E. Sweet showed an engine fitted with a shaft governor which had been built under his supervision by students in the shops of Cornell University. This exhibition seems to have been the inspiration which resulted in the construction of the shaft governor by many manufacturers, and the governor shown (Fig. 4) was the pioneer in the later period of development of this important invention.

This was not the first engine constructed by Prof. Sweet, but was, I believe, engine No. 3. This Centennial engine is still preserved in the Museum of Sibley College, although the original governor was long ago removed. The original governor was

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temporarily removed in 1889 to carry on some experimental work with governors of a different design on the same engine. Some of the parts of the governor were broken and it has never been possible to restore them in the original condition. The shaft governor on the Centennial engine was very different in construc-

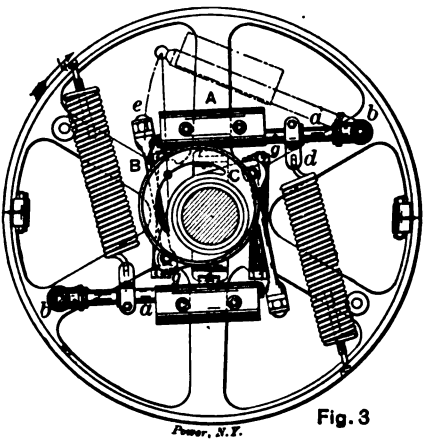
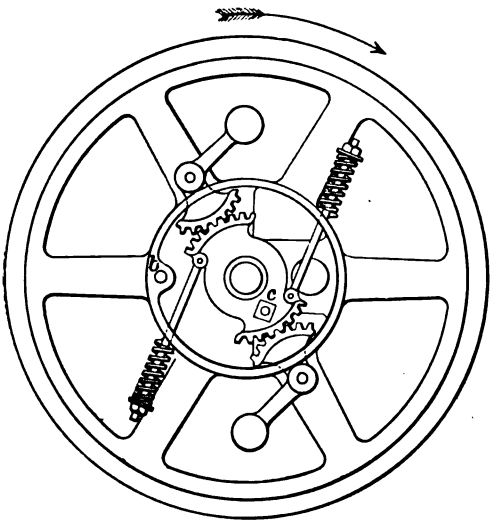


Fig. 3

tion from the later ones designed by Prof. Sweet and from the one now used on the Straight Line engine. The valve rod was connected to an eccentric through the medium of a geared disk.

In later constructions of the governor applied to the Straight Line engine, the valve is connected to a swinging eccentric by link motions.



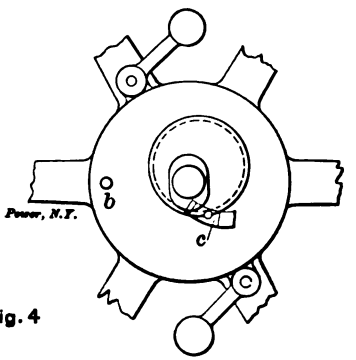


Fig. 4

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My study of the literature of the subject would indicate that the shaft governor is at least, so far as its practical application is concerned, strictly an American invention, and furthermore, this invention has not been introduced to any great extent, even at the present time in Europe, while in England its use is so limited that English writers of text books have not considered it of sufficient importance to merit any mention. In this country the steam engine governor has followed the course of every great invention in its development; it has been developed, not by a single person, or as a single invention, but rather by the slow and tedious process of experiment and practice. As in the steam engine itself, we find, doubtless, first a period of speculation, during which time theoretical investigations were made and patents taken out, and this period probably extended until about 1870; then comes a period of application, beginning in a small way perhaps with 1870 and extending through the next fifteen years, during which time numerous applications of various forms were made, tried with greater or less success, modified and improved until finally a high degree of perfection has been reached.

The earlier form of governor and the one which is almost exclusively used in England and other European countries to-day was invented by James Watt, or at least adapted for use on the steam engine by Watt.

It is hardly probable that Watt ever considered himself as the inventor of the governor for regulating the speed of an engine, for the reason that I do not find this invention claimed in any of his patents, and judging from the character of the claims made in his numerous patents, Watt was not the kind of a man to omit protecting himself for any of his inventions.

In the life of Watt, by Muirhead, it is stated that for the purpose of regulating the speed of the engine Mr. Watt tried various methods, but at last fixed upon what he called the "governor," consisting of a perpendicular axis turned by the engine; to a joint near the top of this axis is suspended two iron rods carrying heavy balls of metal at their lower ends, in the nature of pendulums. When this axis is put in motion by the engine the balls recede from the perpendicular by the centrifugal force, and, by means of a combination of levers fixed on their upper end, raise the end of a lever which acts upon the spanner of the throttle-valve, and shuts it more or less according to the speed of the engine, so that as the velocity augments, the valve is shut, until the speed of the engine and the opening of the valve come to a

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maximum and balance each other. The application of the centrifugal principle was not a new invention, but had been applied by others to the regulation of water and wind mills, and other things; but Mr. Watt improved the mechanism by which it acted upon the machines, and adapted it to his engines.

Such, says M. Arago, in describing Mr. Watt's application to the steam engine of the governor, or regulator by centrifugal force, was its efficacy, that there was to be seen at Manchester a few years ago, in the cotton mill of Mr. Lee, a man of great mechanical talents, a clock which was set in motion by the steam engine used in the work, and which marked time very well, even beside a common pendulum clock.

The principle of action of the simple governor of the revolving pendulum type can be expressed by an equation as follows:

$$h = \frac{g r^2}{v^2} = \frac{g}{4 n^2 \pi^2}$$

from which

$$n^2 = \frac{g}{4 \pi^2 h}$$

$$n = \frac{1}{2\pi}\sqrt{\frac{g}{h}} = \frac{constant}{\sqrt{h}}$$

In this equation n equals the number of turns per second, v the velocity in feet per second, r the horizontal projection of the arm of the pendulum, h the vertical projection of the arm of the pendulum, g the acceleration due to gravity. These equations are well known and the explanation of their derivation can be found in any treatise on the subject. It is noted that the position of the governor balls which are determined by the quantity h does not vary with the speed of the engine, which is represented by the symbol n, but varies with the square of the speed, n^2, consequently a governor of the simple pendulum type cannot be made so as to give a perfectly uniform motion without some change in form or construction not known to Watt. To make the revolving pendulum isochronous in its action many devices have been brought out, and while these have in a great measure improved its action, none of them has been entirely successful. The pendulnm governor has been much improved by arranging it to lift a weight and also by crossing the arms of the pendulum and arranging their point of suspension to one side of the axis. By these arrangements the distance passed through by the moving parts of the governor becomes very nearly proportional to the change in motion of the engine. These governors have also

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been constructed so as to utilize the force of springs instead of that of gravity to counteract the effect of the centrifugal force.

The revolving pendulum governor has usually been constructed to regulate the speed by being attached to a throttle valve in the steam pipe, which was opened or closed as desired. It has, however, been employed in a few cases to regulate the motion of the engine by changing the travel of the steam valve through the medium of a link motion, and in the drop cut-off class of engines to regulate the speed by unlocking the valve mechanism so as to permit closing as in the Corliss type of engine.

Where the regulation is accomplished by throttling the steam supply, poor results are generally obtained for reasons entirely independent of the action of the governor, since necessarily more or less time must elapse before the proper amount of steam to give the desired speed can be made to pass through a throttled orifice. The throttling governor as usually constructed in this country has not been of the highest type of workmanship, nor has it accomplished all of the results in regulation which would have been possible with governors of its type and class, made with better design and workmanship.

The formula to which reference has already been made does not consider the retarding effect of friction. There is perhaps nothing so important in its effect on results of regulation as friction, which always acts to resist any moving force; it tends to prevent the governor balls from moving to their true position whether the motion of the engine is too fast or too slow, and consequently it becomes responsible for irregular action of the governor and for much of the imperfect regulation. It is, however, important to note that the revolving pendulum governor is not theoretically perfect, and aside from imperfections of construction and design it cannot be made to give a perfectly uniform motion to the engine.

In the shaft governor we find in every case a weight supported by an arm or arranged to move in guides connected to a revolving fly wheel, so that the centrifugal force tends to throw it away from the center. A spring is employed to counteract the effect of centrifugal force and is so arranged as to restore the weights to the normal position when the engine comes to rest. In this governor the centrifugal force tends to throw the weighted-portions outward and toward the circumference of the revolving wheel, whereas the spring tends to draw the weight inward and counteract the centrifugal force, holding the governor in such

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position as to maintain uniform speed. By properly proportioning and arranging the weights and the spring, it is entirely possible to make a governor of this class so that its parts will move directly proportional to any change of speed of the engine, and consequently it will take such a position as will tend to keep the motion perfectly uniform regardless of other conditions. In other words, it is possible to make a governor of this class which will give theoretically uniform motion.

The tendency of a moving body to continue its motion uniformly has been well known since the time of Sir Isaac Newton and is generally known as the "principle of inertia." It has been recognized from the earliest times in the art of steam engine building, that heavy fly weeels conduced to uniformity of motion because of the inertia of the parts. This uniformity of motion is a well known function of the weight of the fly wheel. Consequently it has been the practice for years to use heavy fly wheels where a uniform motion is desired, and even at the present time we have found no system of regulation which permits us to do away entirely with that produced by the inertia of heavy weights. The irregular motion produced by the intermittent action of the steam on the piston can be very largely reduced to a uniform action by the use of an extremely heavy fly wheel and the minute variations in speed can probably be controlled by no other method. As the engine is made to revolve at a higher speed the impulses are made at greater rapidity and consequently a fly wheel of smaller weight can be employed for the same degree of uniformity of motion. The shaft governor could, of course, be connected to the throttle of a steam engine and would in that case produce results superior to any of the revolving pendulum governors, but such an application has, so far as I know, never been attempted. The governor has been universally connected through the medium of rods and links directly to the main or auxiliary valve which regulates the supply of steam to the engine. The advantage gained by this construction is that of admitting steam of full power behind the piston at each stroke, and thus giving the full benefits of expansion of the steam in its work.

This advantage is great and will result under usual conditions in a marked improvement in economy, as compared with a throttling engine otherwise the same. I had an opportunity once of testing two engines, one automatic, the other throttling, both in excellent condition, doing alternately the same work.

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The results, which I do not have here in full, showed slightly over 12 per cent. in favor of the economy of the automatic engines, yet the conditions I considered as favorable as possible for the throttling construction.

The shaft governor has proved itself to be especially adapted for engines moving at a comparatively high speed of rotation. The results produced in the way of regulation in engines of this type have been in some instances simply remarkable, as it has been found entirely possible to produce a governor which would hold the engine to the same number of revolutions per minute, whether the engine were running light or loaded, or whether the load were suddenly or slowly applied or removed.

The shaft governor, revolving as it does with the shaft of the engine, is affected by the inertia of its particles in the same manner as the revolving fly wheel. The governor parts may be arranged so that this inertia effect may tend to make its action quicker, in which case the regulation of the engine would be improved, or it may be arranged so as to have the reverse effect, in which case the regulation of the engine would be worse than before. This effect of inertia on the part of the governor and its use for improving the regulation was not recognized until the shaft governor had been pretty well developed, but a study of the drawings of some of the early types of governors show that they were constructed and operated in such manner as to have the full benefit of inertia to aid in the regulation. This seems to

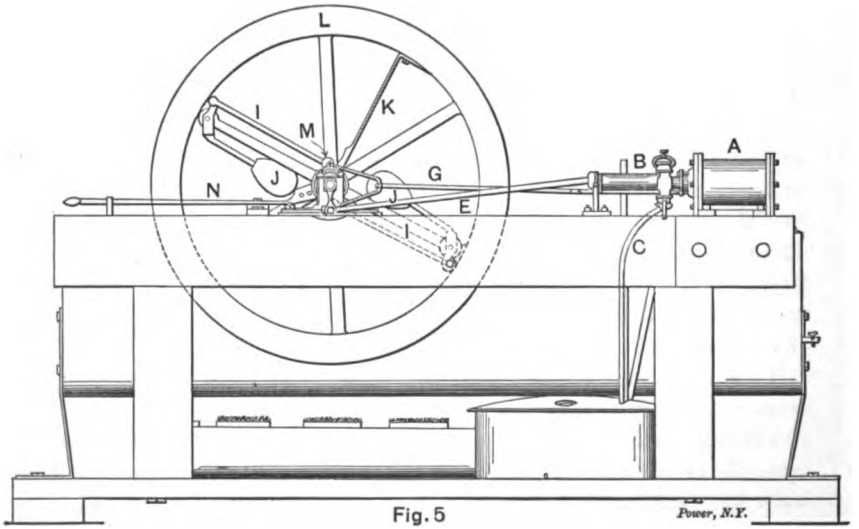

Fig. 5

Power, N.Y.

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have been notably true in the case of the governor shown by Prof. Sweet at the Centennial Exposition.

The records of the American patent office in reference to the shaft governor are of much interest, but time will not permit any extended reference to these records. A few of the earlier patents are, however, considered of so much importance that drawings are submitted and quite full references are given. These early patents do not, probably, represent any practical application, but they are interesting as showing a complete understanding, not only of the theory of the shaft governor, but of methods of application to practical work.

The earliest reference which I have been able to find to the shaft governor is shown in a patent granted J. D. Custer, June

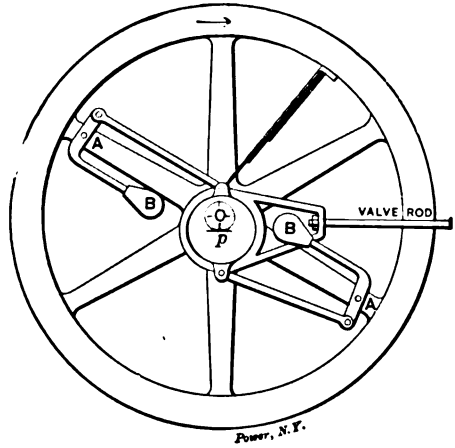

FIG. 6.

21, 1839 (Figs. 5 and 6). From these it will be seen that it consisted of two balls or weights symmetrically disposed in the fly wheel and in gravity balance and pivoted to radial arms and connected by links with the eccentric in such a manner that the action of the centrifugal force would cause the balls to fly out, and this action would twist the eccentric on its centre so as to reduce the travel of the valve. The action of the centrifugal force was opposed by a flat spring. The drawing indicates a form of governor which should have been of practical utility, but I have not been able to find that the governor patented by Custer was ever put into practical use. It is quite certain that this invention did not produce any great change in the art of building steam engines, as the shaft governor seems to have

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been practically unknown for nearly a third of a century after this date.

The next governor patent to be granted was to Lewis Eikenberry, of Philadelphia, April 1, 1862 (Fig. 7). The patent was given principally for an improvement in variable cutoff valves, in which the valve motion was regulated by use of a cam. The shaft governor shown was of peculiar type, in which the pivots or the arms to which the balls were fastened were in the plane of the revolving wheel so that the centrifugal force carried the balls into a position at an angle to the plane of the wheel and nearly parallel to the shaft. This form of governor should have been efficient and effective, but it doubtless would have proved not practicable to apply in numerous cases. The next governor patent was granted to Joab H. Wooster, August 20, 1867, of which no picture is shown, of the same general type as that granted to J. D. Custer; in this patent, however, the eccentric was arranged so as to fit loosely upon the shaft and was connected to the governor in such a manner that it would swing past the center of the shaft, thus changing the lead of the valve. The construction shown in the patent granted for this governor would probably have resulted in a partial success, but I have not been

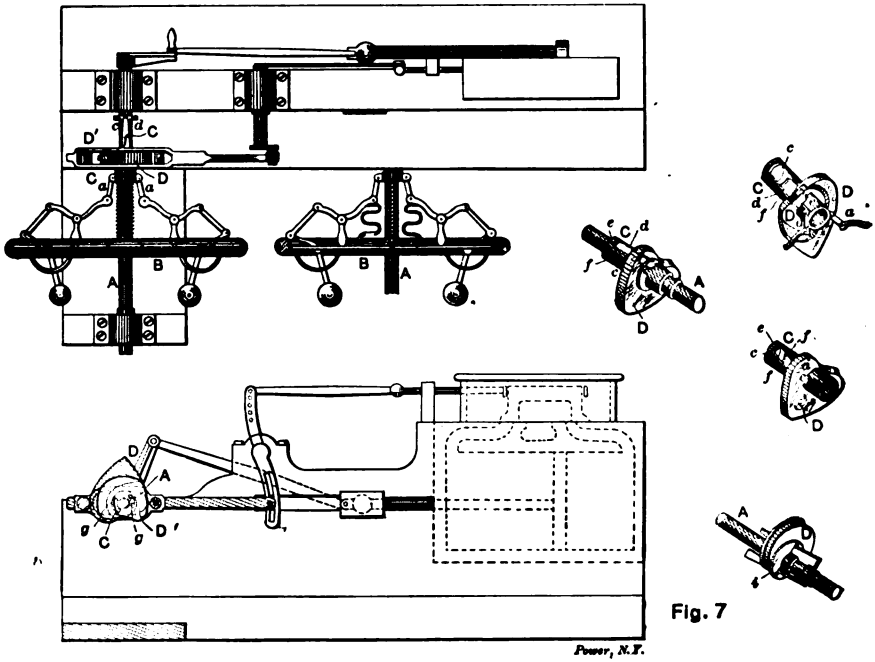

Fig. 7

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able to find evidence which would show whether or not this governor was put into practical operation.

The next patents in order, to which we will refer only by name, were as follows: Samuel Stanton, Newburg, N. Y.. July 14, 1868; D. A. Woodbury, Rochester, N. Y., May 31, 1870, and also September 27, 1870. In the latter patent, which shows a governor used later in the well known Woodbury engine, a distinct statement is made in the specifications regarding the effect of inertia on the parts of the governor, and the arrangement is made so that inertia as well as centrifugal force is employed for governing purposes.

The next patent in order was granted to Joseph W. Thompson, Salem, Ohio, July 15, 1872, and which, with a later one granted April 27, 1875, and still another on January 18, 1878, forms the basis of construction which has been used so long and with such excellent results in the Buckeye engine.

In chronological order patents were granted to John C. Hoadley, October, 28, 1873, and March 17, 1874, for shaft governors, both of which were practically used on the Hoadley engine.

From this time on, patents on shaft governors are exceedingly numerous and cover different forms of mechanical devices and different methods of application of mechanical principles. The improvements of a later date are generally of a nature which resulted in simplifying the construction, reducing the number of working parts, lessening the friction and thus making the governor more perfect in its action.

The shaft governors can be divided into two classes with respect to the motion of the valve, namely:

Class I, in which the eccentric is rotated or twisted around the shaft. The travel of valve is changed without change of lead.

Class II, in which the eccentric is mounted on a disk with a center different from that of the fly wheel and is swung in the arc of a circle across the center of the shaft. The travel of the valve is changed with change of lead.

For both the above classes of valve gear the governor can be essentially of the same character, hence the above distinction does not necessarily indicate a structural difference in the governors.

Neglecting the difference of swinging or rotating eccentric, governors can be divided into three groups, depending on structural differences.

These groups are as follows:

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I. Governors with two weights in gravity balance, as already shown in early examples in the Custer, Buckeye and Westinghouse governors.

II. Governors with a single weight in gravity balance, with eccentric and governor mechanism.

III. Governors with single arm in partial gravity balance which carries inertia weight, centrifugal weight and eccentric.

All the above classes can be operated so as to have regulation assisted or retarded by inertia and can probably be connected to rotating or a swinging eccentric as desired.

A very good illustration of a shaft governor of the first class is shown in Fig. 8. The eccentric is mounted on a plate *G*, pivoted

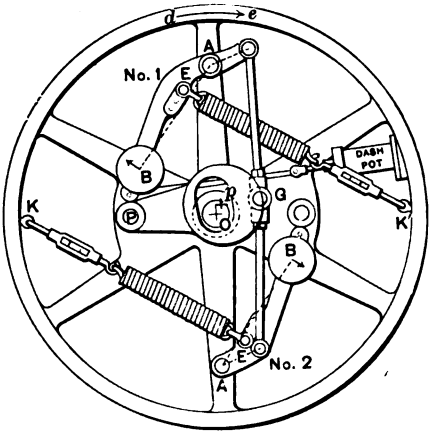

FIG. 8.

at *P*, and is connected to *EB*, No. 1, and *EB*, No. 2, by connecting rods, in such a manner that the action of centrifugal force in throwing the weights *BB* outward cause the center of the eccentric to swing toward the center of the shaft. The springs pivoted at *K* rock against the centrifugal force and hold the weights in a determinate position for each speed. The dashpot simply restrains the motion when too rapid and tends to prevent racing. There are numerous governors in this class.

Fig. 9 represents a notable illustration of a shaft governor in Class II. This governor, although consisting of a single weight, is still in gravity balance. Its advantages over those in Class I are a less number of working parts, simpler construction and less friction. The governor is used on the Straight Line engines and one or two others, and is the latest design of Prof. John E. Sweet.

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Fig. 10 represents a governor in Class III. This governor was designed by different engineers and the patents are now owned by Mr. Frank Rites. It is now in very extensive use in the United States. This governor has a single moving part mounted on a single pivot. It is designed to take full advantage

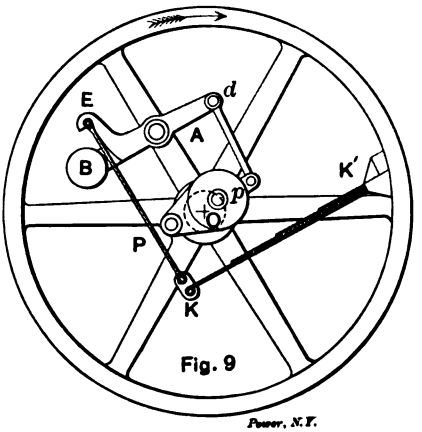

Fig. 9

Power, N.Y.

of inertia, and is so nearly in gravity balance that no bad results in regulation were ever shown by defects in balancing.

The friction in this governor can be reduced to a minimum and the results are great sensitiveness and wonderful regulation under adverse conditions.

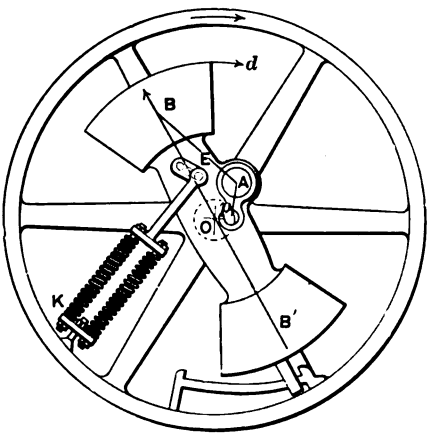

FIG. 10.

The accompanying table gives a list of U. S. patents for improvements in the shaft governor granted previous to 1880, in all only 29, of which 5 were granted before 1870, and 25 between 1870 and 1880. Since that date the patents have been numerous.

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EARLY LIST OF U. S. PATENTS FOR SHAFT GOVERNORS.

(Patents granted prior to 1880.)

1839	June 21,	1,179	J. D. Custer,	
1862	Apr. 1,	34,821		
1862	Apr. 16,	38,055	L. Eikenbury,	Philadelphia, Pa.
1867	Aug. 20,	67,936	Joab Wooster,	Strykersville, N. Y.
1868	July 14,	80,025	S. Stanton,	Newburg, N. Y.
1870	May 31,	103,698	D. A. Woodbury,	Rochester, N. Y.
1870	Sept. 27,	107,746	D. A. Woodbury,	Rochester, N. Y.
1872	July 16,	128,986	J. W. Thompson,	Salem, Ohio.
1875	April 27,	162,715	J. W. Thompson,	Salem, Ohio.
1873	Oct. 28,	144,098	J. C. Hoadley,	Lawrence, Mass.
1874	Mar. 17,	148,560	J. C. Hoadley,	Lawrence, Mass.
1875	June 29,	164,917	J. C. Hoadley,	Lawrence, Mass.
1875	June 29,	164,942	G. C. Suiss,	Lawrence, Mass.
1875	July 20,	165,744	H. S. Maxim,	Brooklyn, N. Y.
1875	Aug. 31,	167,225	Corbitt & Campbell,	Milwaukee, Wis.
1875	Sept. 21,	167,835	J. Felber,	St. Louis, Mo.
1876	Jan. 11,	172,116	Hall & Whitteman,	Hasma, N. Y.
1876	Sept. 5,	181,927	G. F. Ernst,	St. Louis, Mo.
1876	May 11,	184,443	G. R. Tower,	Annapolis, Md.
1877	Jan. 9,	187,116	Cosgrove,	Faribault, Minn.
1878	June 18,	204,924	Thompson & Hunt,	Salem, Ohio.
1878	July 30,	206,500	H. Tabor,	Corning, N. Y.
1878	Aug. 6,	206,792	C. B. Smith,	Newark, N. J.
1878	Sept. 3,	207,607	D. O. Ladd,	Chicago, Ill.
1878	Sept. 3,	207,608	D. O. Ladd,	Chicago, Ill.
1879	Jan. 14,	211,309	L. H. Watson,	Chicago, Ill.
1879	Jan. 14,	211,335	C. S. Locke,	Chicago, Ill.
1879	Mar. 18,	213,395	G. H. Cobb,	Palmer, Mass.
1879	Nov. 4,	221,296	F. Fordick,	Fitchburg, Mass.
1880	May 25,	227,967	C. V. B.,	San Francisco, Cal.
1880	Aug. 17,	231,228	W. Johnson,	Lambertville, N. J.

The limits of this paper do not permit an opportunity for further discussion of the various forms of shaft governor, or of its theory and method of action. The account of the development is imperfect for the reason that the sources of information available were neither numerous nor exhaustive, but it is to be hoped that various members of the association will supplement the facts gathered together and presented in this short paper, with data relating to the development of the governor, while it is still fresh in mind.

There are many reasons for obtaining this information fully and in detail while there is an opportunity. Such investigation as made indicates that the shaft governor as we know it to-day is

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essentially an American invention, conceived, developed and perfected in this country.

The importance of this system of regulation is so fully recognized as to need no argument in its favor, and while at the present time the shaft governor is used only in an experimental way on certain classes of engines, yet the few experiments which have been performed indicate that its field is not limited to any great extent by speed requirements, and it seems reasonable to suppose that a period of development may extend its use to include not only all classes of steam engines, but gas engines as well.

The demand for close speed regulation came with the invention of the incandescent light generator, and as has been the case in many illustrious examples, the demand proved to be the incentive that led to the supply of the apparatus required. Then recently, with the introduction of the alternating current generators, has come the demand for running two or more of these generators in multiple, and the requirement of a speed regulation which shall keep the electric pulses uniformly together throughout all the different parts of a revolution. This demand is more difficult to meet than that of uniformity in number of revolutions per minute, as it requires uniform angular motion at all times. It is required that the speed of two generators delivering alternating current into the same main, if allowed to vary in the least, must vary exactly alike, not only as to the total number of revolutions per minute, but as to the angular displacement within extremely narrow limits, within each revolution.

This requirement, severe as it may seem, will certainly be successfully met by the shaft governor, yet we must perhaps admit that for this new and rigid demand in regulation the shaft governor has still before it a "period of development." Its wonderful quickness of action, which was so necessary to preserve a uniformity of total number of revolutions per minute under the worst possible conditions of variation, has proved for this new requirement a "detriment" rather than a help. Knowledge of the speed requirement demanded, together with experience and practice, will soon serve to point out to the American engineer the proportions of fly wheel and of governor parts necessary to perfectly meet the demands for this service.

The practice of using light fly wheels, which the shaft governor has made possible in the past, thus contributing much to reducing the cost of manufacture, will doubtless have to be modi-

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fied to meet the new demand for infinitesimal angular variation, but with heavier fly wheels to preserve uniformity of motion throughout the fractions of a revolution, there is every reason to believe that this regulator will meet every demand made for uniformity of speed.

In conclusion I will say that I believe the engine builders of America are to be congratulated for the almost perfect regulation which has characterized their productions in the past, and this favorable condition is in a great part to be ascribed to the invention and development of the shaft governor.

My attention has recently been called to an excellent paper on the subject of the shaft governor, the paper being written by Wilson Hartnell, of Leeds, England, and entitled "Automatic Expansion Gear." It was read before the Institution of Mechanical Engineers of England, in 1882. The article contained a description with illustration of two forms of shaft governor designed by the author, and also an exhaustive treatise on the principles of design of the governor. It is one of the most complete articles ever written, and is worthy the closest study. The article tends to show a limited use of the shaft governor at a very early date in England, and serves to raise the question as to why more attention has not been given to this important method of regulation in later times.

The University of the State of Missouri has just issued a bulletin describing its "Growth in Eleven Years (1890–1901)." Endowment has increased from $540,000 to $1,236,000; income from $122,000 to $420,000; buildings, books, and equipment from $360,000 to $1,300,000; students from 510 to 1575; faculty from 38 to 86. In the faculty are six Cornell alumni, this number being exceeded only by Harvard (15), Johns Hopkins (8), Berlin (10), and Missouri itself (22). As to the students, "in the next five years the enrollment will go beyond 3,000, probably."

The *American Telephone Journal* is authority for the statement that Purdue University is about to inaugurate a course in practical telephony, being "the first technical school to recognize telephone engineering as worthy of special consideration." It may be remarked that the Clarkson School of Technology, Potsdam, N. Y., offers such a course.

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THE ELECTROLYTIC PRODUCTION OF ALUMINUM.*

JOHN W. LANGLEY.

The process of manufacturing aluminum may be considered both from the theoretical and the practical side. Taking up first the theoretical side, we know that the conditions for successful electrolysis are that the substance to be decomposed must be in liquid condition. Now, since oxide of aluminum is infusible at all ordinary furnace temperatures and is practically insoluble as such, it is evident that a solvent of some kind must be employed, but if aqueous solutions are used, the breaking strength of the water molecule being about 1.5 volts, whereas the breaking stress of aluminum oxide is in the vicinity of 3 volts, it follows that no aqueous solution of aluminum can be electrolyzed, since the current energy will be expended upon the water and not upon the aluminum. The basis of the present industry consists in the discovery of a solvent for aluminum which is at the same time able to dissolve large quantities of it and also too itself possesses a breaking stress higher than that of the alumina molecule. This substance is the mineral cryolite, having the symbol Al_2F_6 Na_6F_6. This substance melts at a strong red heat and is able to dissolve 26 per cent. of its weight of alumina oxide, Al_2O_3.

The practical method consists in forming a carbon vessel, which is done by lining a tank made of boiler iron which is about 6 feet long and 4 or 5 feet wide. This is lined with carbon for 5 or 6 inches in thickness. This tank is made the negative end of the circuit. The positive or anode side of the circuit is formed of carbon cylinders 3 inches in diameter and from 30 to 36 inches long. These have a ⅜ inch hole drilled in one end of them into which is driven a ⅜ inch copper rod about 5 feet long. These anodes to the number of 12 or 14 are suspended over the carbon lined pot from 2 massive copper straps to which they are fastened by ordinary square clamps, so that they may be easily adjusted both vertically and laterally. The lower ends of the carbon cylinders are separated from the bottom of the cathode pot by about an inch to an inch and a half. Then the pot is filled with melted cryolite containing alumina, to a depth of some 4 or 5 inches. The current employed is 7000 amperes, thus giving for the current density for each of the carbon rods 500 amperes. The

* Abstract of lecture before Sibley College, March 14, 1902.

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result of this high current density is the production of a large amount of local heat which is quite essential to the carrying out of the process, for the bath requires to be maintained at about the temperature of melting copper. The production of this heat is due to the high current density, and we can best understand how great this is by comparing it with the deposition of copper in the process of the electrolytic refining of copper, where an aqueous solution is necessarily employed. In this case the maximum current density which can be employed is about 100 amperes to the square yard; whereas the density employed in the aluminum manufacture is 23,976 amperes per square yard, which is practically 240 times the density for copper plating; and it is a fortunate fact and essential for this operation that the aluminum is able to be deposited at this very high current density, this being doubtless owing to the fact that the aluminum is above its melting point and consequently is liberated in the liquid condition. Were this not the case, a great obstacle to the employment of this process would enter the problem, for the maintenance of the required temperature within the bath would necessitate the use of such a high temperature outside as to melt the iron tank.

As to the economy of the practical process, the voltage across the tank is 7, and it requires about 18 E. H. P. hours to form one pound of aluminum for each one of these pots and there are from 12 to 24 employed at once, which yields about 87 pounds of aluminum every 24 hours, per pot.

Now, comparing the above practice with the theoretical yield, and taking the constant for the deposit of aluminum as .3364 grms. per ampere hour, and the true voltage of electrolytic deposition as being 2.4 volts as I have determined it on several occasions, we see that a pound of aluminum should be theoretically produced by 4.28 E. H. P. hours. The efficiency of the process appears therefore to be low, inasmuch as there are upwards of 13 E. H. P. hours converted into heat, but on the other hand if we remember that this heat is essential to the operation and is obtained without the burning of fuel in the ordinary sense, we see that the process is really a highly efficient one.

The metal aluminum possesses chemical energies of great intensity and it is interesting to remember that every pound of this metal contains within it in the form of potential energy 4.28 E. H. P. hours, or that the metal contains energy enough to raise it against the action of gravity nearly 2,000 miles.

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The metal is removed from these pots or electrolytic tanks either by bailing with a cast iron ladle or by tapping it out. It is then remelted to separate it from the adherent slag, and cast into ingots. The high degree of purity which the metal must have for most commercial purposes is readily attained by using a very pure form of aluminum oxide, and because of the fact that the first few batches of metal which are made collect and consequently eliminate all of the impurities in the ordinary cryolite, which impurities consist mainly of lead, sulphur, phosphorous and silica, and since the cryolite does not suffer electrolytic decomposition, it can be used over and over again indefinitely, so that after the first 3 or 4 batches of metal have been removed from one of these tanks, all subsequent metal produced will have a degree of impurity due only to the original aluminum oxide employed, and which can be obtained commercially with a degree of purity sufficient to enable the metal to show 99.6% pure.

[The lecturer is Professor of Electrical Engineering at the Case School of Applied Sciences, Cleveland, Ohio. He is familiar with his subject from every point of view, chemical, physical, commercial and practical, on the scientific and on the industrial side as well. He has had a life-long experience as chemist and physicist and in the metallurgical industries; having been a professor teaching the two sciences since his youth, at the U. S. Naval Academy, at the University of Michigan, and now at the Case School of Applied Science; having been for several years the chemist and investigator for a firm of Pittsburg manufacturers and as consulting chemist and physicist and as legal expert, having been frequently employed to investigate and exhibit the practical and scientific side of the work.]

INKLESS PRINTING.—A recent exchange imparts the following information: "Certain chemicals mixed with the paper pulp yield, when touched with an electric current, a dense black mark, which is indelible. Ordinary presses, divested of the inking mechanism, can be fitted with the electric apparatus. One wire of the circuit is attached to the type plate and the other to the cylinder that presses the paper against the type. The current causes every spot in relief on the type to print its form on the paper, without the dampening and smearing caused by ink. The current passing through an incandescent lamp is sufficient to do all the printing on a large press."

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ANALYSIS OF THE STEAM-ENGINE CYCLE.

R. H. THURSTON.

Rankine's analytic discussion of the thermodynamics of the cycle of the standard forms of steam-engine is based upon the assumption of a representative thermodynamic ideal which is that form which is illustrated by an indicator diagram taken from a well-designed engine with a good trip-gear such as that of Corliss or Greene. It is composed of an induction line of constant pressure, an adiabatic expansion line, a terminal exhaust-line of constant volume and a back-pressure line of constant pressure, finally closing the diagram by a line of constant volume. In other words it receives steam at boiler pressure, cuts off sharply, expands as if the cylinder were non-conducting, drops the pressure instantly at the end of the stroke from the terminal to the back-pressure and exhibits no compression or steam-lead. This diagram is seen in the accompanying figure.

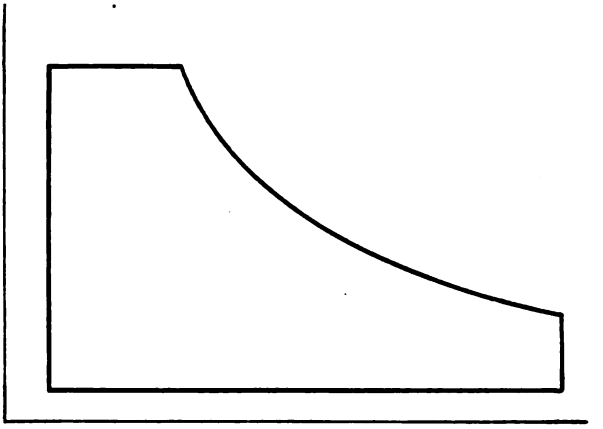

Fig. 1

In discussing this case, Rankine, through one of his many curious and ingenious devices, his inventions, in fact, secures an exact, a rational, measure of the portion above the terminal pressure line, obtaining an expression for the quantity

$$U_1 = \int_{p_2}^{p_1} u\,dp$$

which can be integrated, and this added to the value of the

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rectangle under the terminal pressure line, $U_2 = (p_2 - p_3)\, u_2$, gives the total quantity of energy conversion for the case ; this is

$$U = U_1 + U_2 = J\,[T_1 - T_2(I + \log_e T_1/T_2)] \qquad \text{I.}$$
$$+ H_1(T_1 - T_2)/T_1 \qquad \text{II.}$$
$$+ (p_2 - p_3)\, u_2. \qquad \text{III.}$$

H is here the "latent" heat of vaporization, J is "Joule's equivalent," v and u respectively, are the specific volume of steam and the volume of the unit weight of steam and water at any point on the expansion line.

It is at once seen that this expression divides itself into three parts : a function of temperature which will be found to measure the work of compression in the Carnot vapor-cycle, a term measuring the Carnot energy-transformation, and the third term measuring the work obtained between the terminal and the back-pressure.

The construction of this rational and exact formula is based upon the device by means of which Rankine obtained an exact value of u. He observes that, along the adiabatic, the entropy, or as he calls it, the "thermodynamic function", $\int \frac{dH}{T}$, is constant and we thus have

$$\int \frac{dH}{T} = J \log_e T + dp/dT \cdot u = J \log_e T_1 + v_1 \cdot dp_1/dT_1;$$

$u = [J \log_e T_1/T + v_1 \cdot dp_1/dT_1] \div dp/dT$; also, $H/I = v\, dp/dT$. Then, as above,

$$U_1 = \int_{p_2}^{p_1} u\, dp = J[T_1 - T_2(I + \log_e T_1/T_2)] + H_1(T_1 - T_2)/T_1.$$

This admirable invention permits an interesting analysis of the case in hand.

The first term of the second member of the full expression may be derived by making H zero in the process of construction of the equation ; thus obtaining the value of the work required in the Carnot cycle to produce compression from the final to the initial pressure when the result is the reduction of the mixture in the cylinder to the condition of water at maximum temperature and under maximum pressure, or conversely, where unit weight of water is expanded from the upper to the lower limit. Comparing this value of work with the work of a Carnot cycle utilizing the same heat-supply, it is at once found that this work

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which is gained by change from the Carnot to the Rankine, or the Corliss, cycle is obtained at a sacrifice of efficiency.

The second term constitutes a larger and larger proportion of the whole, as the terminal pressure on the expansion-line approximates to the back-pressure, and as compression is introduced more and more nearly in accordance with the prescription of Carnot: *i.e.*, as the cycle approximates in form and action to that of the "perfect-engine cycle". This means that the proper source of mechanical energy in the steam-engine and other vapor engines is the "latent" heat of vaporization at the temperature of the boiler. The utilization of the sensible heat of the fluid is effected in this cycle only at a net loss of mechanical energy. The heating of feed-water is a boiler economy compelled by the defective action of the engine and, so far as the engine and the thermodynamic conversion are concerned, it should be neither necessary nor possible.

The third term measures the work on the diagram represented by the rectangle below the terminal pressure, and this obviously reduces efficiency in proportion as the terminal pressure is high and the ratio of expansion is low. With the terminal pressure usual in our best engines, however, this is actually a proper adjustment, as the gain by further expansion in the real engine is more than compensated by non-thermodynamic losses, such as by friction, by enlargement of the working cylinder for the given amount of work delivered and by increased "cylinder condensation."

The relation of magnitude of these several parts of the diagram changes with change of working conditions, and it is sometimes desirable to know in what manner and to what extent these relations thus vary. This has been, annually, for many years, a subject of examination in the course of the work of young thermodynamists in Sibley College, and the following is an illustration of such a study of the case where the actual operation is considered of a non-condensing engine supplied with steam at 100 pounds pressure, by gauge, and with a back-pressure of 2 pounds (114.7 and 16.7 absolute), with expansion varying from full stroke to a ratio of ten. The engine employed for comparison was 18 inches diameter of cylinder and 42 inches stroke of piston, making 85 revolutions per minute and rated 200 horse-power at a ratio of expansion of 4. The accompanying plate exhibits the results of this study.

It is at once seen that the values of U rise rapidly between ratios of expansion from unity to 3 and 4, become nearly constant to 6 and 7 and then fall off.

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The quantity measured, it is to be remembered, is not the power of the engine or the work in its cylinder as a total, but the work obtained from one pound of steam thus expanded between the limits of temperature and pressure prescribed for this engine. The quotient of the measure of the work of the horse-power-hour by the work of the pound of steam as here com-

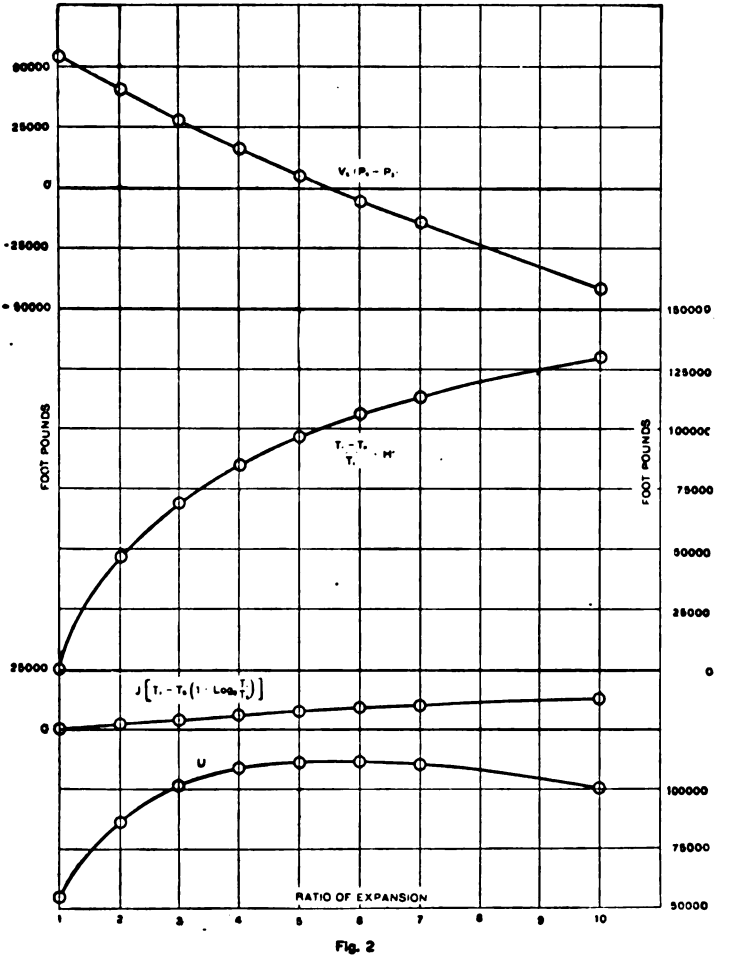

Fig. 2

puted gives the quantity of steam per horse-power-hour for this ideal case and affords a measure of the wastes of the real case by comparison of this figure with that obtained by test.

The value of the Carnot transformation is seen to be augmented rapidly throughout the whole range of the investigation,

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though the gain is lessening sensibly toward the higher values of the ratio of expansion. Its value increases five times between cut-offs at two-thirds and one-tenth and about twice between expansion ratios of three and ten.

The values of the first and of the third terms are in an almost rectilinear series; but the former steadily but slowly increase while the latter as constantly decreases, changing much more rapidly.

The point of intersection of the line exhibiting the work of the exhaust period with the zero line of its diagram, about 5.5, ratio of expansion, shows the limitation in this case due to the presence of an external atmosphere, and a comparison of this figure with that at which the rating of the engine is established shows to what extent practical considerations have compelled a variation from the conditions of maximum thermodynamic efficiency; the ratio of expansion being decreased in practice above fifty per cent. in this instance. With simple condensing engines this difference is often enormously greater, especially with the older machines; as where it has sometimes been reduced from the ideal, about forty, to as small a figure as two, or, in modern engines, from between fifty and one hundred, to ten or twenty.

Throughout the whole economical range, whatever it may prove to be, it is seen that the value of the first term in the series, that of work obtained from sensible heat, constitutes but a small part of the total, and even that which is obtained is secured at a loss as compared with the economy of utilization of the "latent" heat of the fluid. This latter available work is in fact derived from the "external latent heat" of vaporization by direct conversion, and the magnitude of the "external latent heat" has the proportion to the "total latent heat" which the cycle-range of temperature has to the total absolute temperature at which the "latent" heat enters the fluid. A Carnot cycle, therefore, may be defined as one which, in a vapor-engine, secures the return, in maximum degree, in the mechanical work at the piston, of the value of the "latent heat" of the vapor. This heat is in part transformed into external work in the process of vaporization, acting against the resistance which is provided by the engine-piston, and is transferred as mechanical work through the movement of the piston during the period of expansion of the liquid into vapor.

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THE NERNST LAMP.*

ALEXANDER J. WURTS.

In 1898 Mr. Westinghouse, recognizing the great commercial possibilities of the Nernst lamp, placed the problem of improvement and commercial adaptation in the hands of the speaker, to whom a happy choice brought as co-workers Mr. Edward Bennett, Mr. Marshall W. Hanks, Mr. Frederick M. Goddard, Mr. M. C. Beebe and Dr. von Recklinghausen.

It is not my purpose to describe the details of our experiments, but to give the results of our work. Let us begin with the glower, so named to distinguish it from the filament of the incandescent lamp.

Our standard 220 volt glower is about 25 mm. long and .63 mm. in diameter. It is made by expressing from a die a dough made of rare earths mixed with a suitable binding material, cutting the porcelain like string, drying, roasting and finally attaching lead wires. This sounds very simple, but the art of making glowers is the result of long and painstaking investigation, particularly with reference to the terminal connection between the glower and the lead wire. This connection as Dr. Nernst made it, consisted of a few turns of platinum wire wound around each end of the glower, the convolutions being finally pasted with cement. This forms a good terminal, but the shrinkage of the glower away from the platinum coils sometimes causes the contact to deteriorate.

The glower is a non-conductor when cold, becoming, however, a conductor when heated, oxygen being desirable also, if not necessary for its successful operation. It is also an electrolyte, and with the direct current the electrolytic action and deposit of platinum black is quite marked and causes a deterioration of the light. The life of a glower on alternating current is about 800 hours, but considerably less on direct current.

The glower is about as strong as a piece of porcelain of the same size and it is quite difficult to break a short section. When properly made, the voltage of a glower changes but slightly during its life, the tendency being to rise from two to four per cent in 800 hours. For a short time before rupture the voltage rises rapidly, until the glower is broken.

*Abstract of a lecture delivered before Sibley College, May 14, 1902. For Figures 3, 4, and 5 we are indebted to the courtesy of *Electrical World and Engineer.*

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The characteristic of a glower with reference to voltage and current is remarkable, and has given rise to the necessity of a steadying resistance. As the current in the glower is increased, the voltage across its terminals rises, at first rapidly, and then more and more slowly to a maximum, beyond which it again drops off with increasing rapidity as the current and resulting temperature through the glower continue to increase. Beyond the point of maximum voltage, the decrease in resistance of glower is so rapid as to make the current difficult to control; in fact, without a steadying resistance such a conductor would rapidly develop a short-circuit and flash out.

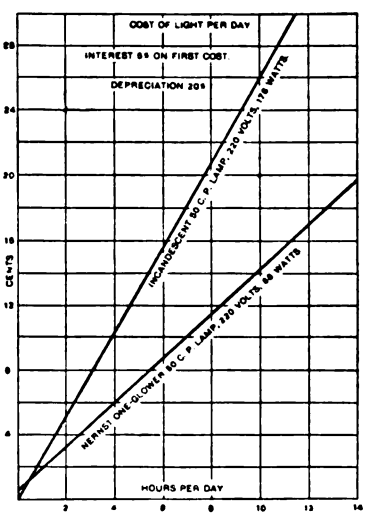

FIG. 1.

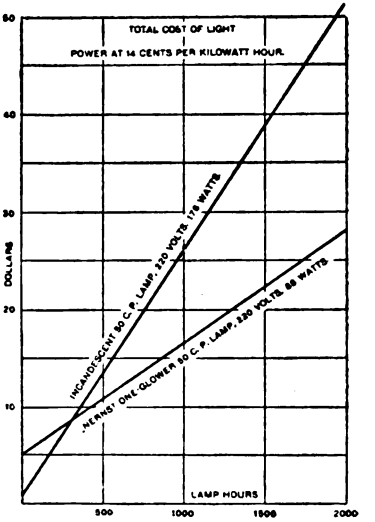

FIG. 2.

The advantage to be gained by the use of a steadying resistance which would enable the glower to be operated efficiently at a point on or beyond the crest of the characteristic curve, was well recognized. To accomplish this under all conditions of commercial use, and with as little loss as possible under normal conditions, the steadying resistance should have as large a positive temperature correction as possible, and this temperature correction should always be immediately available. For example, if the glower were operated on or beyond the crest of the characteristic, the current could obviously be controlled by a sufficiently large steadying resistance having no temperature correction; but such resistance would very materially decrease the

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net efficiency of the glower. On the other hand, if the resistance is assumed to have a high temperature correction, the necessary steadying resistance under normal conditions may be very much less than when no temperature correction is present, and then should there be an increase in E. M. F. above normal, the corrective power of the steadying resistance would be brought into play to check any abnormal flow of current through the glower: but, as already stated, the temperature correction should be immediately available, for if it were not, the glower would "shoot-over" when lighting above the normal pressure, that is, take more current at the start than it would a little later after the temperature correction of the steadying resistance had asserted itself. This would also be the case with any sudden increase in the E. M. F.

Mr. Potter has designed a steadying resistance or "ballast," as he has named it, which is certainly unique in construction, and which meets in a very effective manner the peculiar requirements of the glower. Iron wire is used on account of its high temperature correction, and by properly mounting this in a glass tube filled with some inert gas, he has secured a ballast having at once a high corrective power with minimum resistance at normal. The remarkable characteristic of the ballast shows that with a 10 per cent rise in current, the resistance of the ballast increases 150 per cent, so that a glower thus protected becomes at once operative throughout a wide range.

As already stated, the glower is a conductor only when heated. For practical service in a lamp, therefore, it is necessary that some means be provided for heating the glower and bringing it to a conducting temperature. The glower is lighted at a temperature of 950° C, and it will be readily apparent that to acquire such a temperature quickly and without rapid destruction of the heater and adjacent parts, renders the selection of the materials a serious problem. Platinum for the heater seems expensive for a commercial lamp, and though many attempts have been made to devise a cheap mineral heater, platinum is still most desirable; the running cost of the heater is small, as the scrap is worth 90 per cent of the original cost.

The heater consists of a thin porcelain tube overwound with a fine platinum wire pasted with cement. These tubes are wound for 110 volts, and are connected in pairs of twos, according to service. These heater tubes are mounted on a porcelain support in such a way as to afford easy access for repairs without remov-

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ing the glowers. The life of the heater when running continuously is about 200 hours. Inasmuch as the heater is not called into service more than about 30 seconds to light the glowers, it would have a practically infinite life, were it not for its close proximity to the highly heated glowers.

An automatic lamp must have an automatic cut-out to disconnect the heater from the circuit as soon as the glower shall have lighted. The cut-out involves a coil, a moving member and a contact, all of which must function at a temperature of 110° C, without possibility of failure. The coil must therefore be heat-proof, the contact must not weld, and the moving member should not burn on alternating current. These requirements are severe, but they have all been met in a most effective and satisfactory manner by embedding the coil in cement, by making the contact of silver, and by suspending the moving member from a single point of support.

The lamps thus far developed are indicated in the following table:

C. P.	Voltage.	No. of Glowers.	Style.
50	110	1	Indoor.*
50	220	1	" *
100	220	2	"
170	220	3	"
400	220	6	" *
2000	220	30	"

*Also outdoor.

The main features are the same in all. The indoor lamps are provided with ornamental spun brass housings; the outdoor lamps with neat japanned cast-iron housings.

We will examine in detail the six-glower lamp as typical of all the others. The lamp is suspended from an eye-bolt, which being removed allows access to the inner parts. On removing the housing we find the ballasts placed in a semi-circle around the cut-out, the arrangements of the parts being such as to make all easy of access. The connections are made with small aluminum plugs on the ends of the inter-connecting wires to avoid the many familiar inconveniences associated with set-screws.

All the parts are mounted on porcelain; in fact there is no combustible material whatever in the lamps. The heaters and glowers are attached to a removable piece or "holder," the design being such that the heaters, backed by a porcelain disk, are immediately above the glowers, resulting in the following advantages: Stagnation of the heat from heater, thereby lighting glowers in minimum time; no shadows, nearly all of the light being thrown

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downward, where it is ordinarily most desired; stagnation of the heat from the glowers, whereby they operate in their own heat and therefore at high efficiency. The glowers and heaters are attached to the binding-posts of the holder by means of small aluminum plugs, so that perishable parts are easily changeable. The holder is provided with nine contact prongs, which, when the holder is pushed up into the lamp, automatically makes the desired connections.

The quality of the light is remarkable for its beauty and close approximation to day light. All colors are seen in their proper shade, making the light especially desirable in stores, art galleries, drawing rooms and the like. The absence of shadows, the steadiness of the light, the simplicity and low cost of maintenance, the high efficiency of the lamp and the fact that it is operative on 3000 alternations are features which will recommend themselves strongly to the lighting world.

It is not an easy matter to state the efficiency of a light, and the difficulties are especially pronounced in the case of the Nernst lamp. It would seem desirable, therefore, to give results of various methods of measurement and comparison rather than to make any definite statement based on any particular method or set of readings. A 220-volt glower, operating on its normal current of 0.4 of an ampere, requires 20 volts more in the open air than when burning with 5 others in a three-inch globe. This is due to the glower's operating in a heated atmosphere, which makes the efficiency in direction of greatest intensity 1.2 watts.

A more satisfactory statement will be found in the accompanying table, giving results of comparison with alternating current and direct current enclosed arc lamps:

				Mean Intensity in H. U.						Watts per Mean H. U.					
				Spherical.			Lower Hemisphere.			Spherical.			Lower Hemisphere.		
	Voltage. . .	Current. . .	Watts. . .	Opal Outer.	Clear Outer.	Shade. . .	Opal Outer.	Clear Outer.	Shade. . .	Opal Outer.	Clear Outer.	Shade. . .	Opal Outer.	Clear Outer.	Shade. . .
6-Glower	220	2.35	517	*149	. .	147	*240	. .	279	*3.47	. .	3.5	*2.15	. .	1.85
A. C. Arc.	110	6.29	†417	130	159	152	. .	:90	254	3.21	2.62	2.49	. .	2.23	1.48
D. C. Arc.	110	4.9	539	177	207	. . .	.	272	. .	3.03	2.60	. .	. .	1.98	. .

An opal inner globe or heater-case was used in all cases except the four readings marked *, in which a clear heater-case and sandblasted spherical globe were used.
† Power factor = 0.6.

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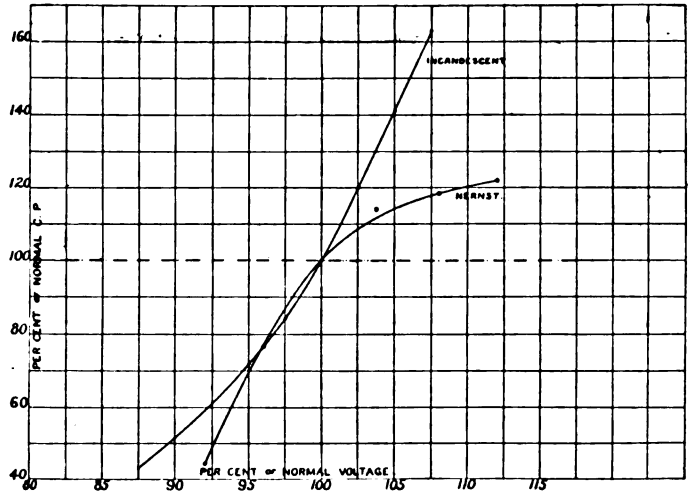

FIG. 3.

The arc lamp figures were taken from the report of the Committee for Investigating the Photometric Values of Arc Lamps, read before the National Electric Light Association, in May, 1900. From this table it will be noted that the spherical efficiency of both arc lamps is better than the Nernst, but if we consider only the floor or desk illuminating power of the lamp, particularly the mean of the lowest 30 per cent. zone, the efficiency of the enclosed alternating current arc lamp is 1.56 watts against 1 watt for the Nernst, and the mean of the lowest 60 per cent. zone for enclosed arc is 1.45 against 1.23 watts for the Nernst. Comparisons between the illuminating powers of the Nernst and incandescent lamps indicate a watt consumption in the Nernst lamp a little less than half of that in the incandescent for the same illumination.

The two sets of curves, Figs. 3 and 4, show interesting comparisons between the Nernst and incandescent lamps under con-

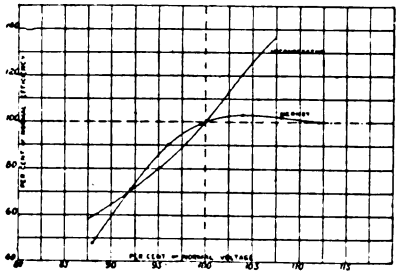

FIG. 4.

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ditions of varying voltage. Fig. 3 shows the relative change in candle power and Fig. 4 the relative change in efficiency. The remarkable steadiness of candle power in the Nernst lamp when forced above normal voltage is due to the corrective power of the iron ballast.

The performance of the lamp is quite remarkable, and already their operation has assumed considerable proportions. As early as July, 1901, about 50,000 c. p. were in use around East Pittsburg, while the interior of the dome of the Electricity Building at the Pan American was brilliantly lighted with these lamps. Runs have been made on the regular circuit of the Allegheny County Light Company, which is noted for its poor regulation, and it was found that, in spite of the fact that the pressure varied from 4 per cent. below to 7½ per cent. above normal, the lamps stood it well and averaged a life of glower of about 890 hours.

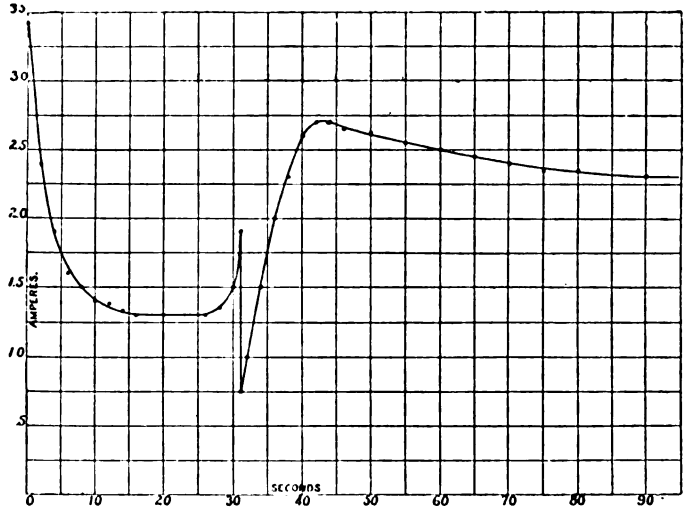

FIG. 5.

In connection with this topic, it will be interesting to note just what is going on in the lamp during the time of lighting, also during service under varying conditions of line voltage. Referring to Fig. 5, we have a curve showing the current taken by a six-glower 220 volt lamp during the lighting period. As the current is turned on, there is a sudden rush of nearly 3.5 amperes through the heater, which, owing to the temperature correction of the platinum wire, is quickly reduced to about 1.3 amperes. At the end of 26 seconds, the first glower begins to light, at the

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the end of 30 seconds the second glower is lighted and the heater cut out, the current dropping at once to .75 amperes; the remaining glowers then light rapidly until at the end of 42 seconds all the glowers are lighted. From this point there is a slight drop in the current until the lamp reaches its normal running temperature.

When the lamps are first started they require no attention. After 1,000 hours, however, the renewals become fairly regular, and our experience shows an average life of 800 hours for the glowers, 2,000 to 3,000 hours for the heaters, and an indefinitely long life for the ballasts. The lamps are examined through a colored glass to see if all the glowers are burning; if some of the glowers or heater tubes are burned out, a new holder is put in and the old one refitted. This is easily done at the central station or in the shop itself where many are used, and a few refitted holders should be kept in reserve, for they are as easily substituted as an incandescent globe. It is too early to say anything definite about the cost of these lamps, but the chances are that they soon will be permanently listed. It is estimated that the renewals will cost less than for arc lamps, and provision will be made for return of the perishable parts containing platinum.

In closing let me say that the Nernst lamp can in no sense be considered an experimental device. The development of details connected therewith has continued until all question of doubt as to its commercial success has been removed by the operation of a large number of lamps of various sizes and finished pattern for extended periods under commercial conditions, and it is confidently felt that the splendid exhibit of these lamps, which could be seen at the Pan American Exposition, will prove a fitting demonstration of the complete and thorough manner in which the brilliant discovery of Dr. Nernst has been taken up and pushed forward in America.

The Thomas S. Clarkson Memorial School of Technology, of Potsdam, N. Y., (William S. Aldrich, Director) has issued an attractive catalogue, in which especial attention is invited to the course offered in Mechanical Engineering. This is modelled after Sibley College, though on a very much smaller scale. Shop-work forms there, as here, a prominent feature.

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PROCEEDINGS OF THE ROYAL SOCIETY OF GREAT BRITAIN.

Vol. XVI, Part II, contains a number of papers of peculiar interest in the field of applied science and engineering.

The opening article is by Lord Rayleigh, on 'Flight.' In this paper it is stated that the main problem in flight is that of the aeroplane, as in the case of the kite. But the kite is anchored and at rest relatively to the earth; while the aeronaut, the aviator, whether human or other, is adrift. No bird can maintain itself in motion in a uniform wind-current without active exertion any more than in an atmosphere at rest. Soaring is thus evidently the outcome of utilization of internal movements of the atmosphere surrounding the bird. The albatross presumably takes advantage of such movements where strata move in proximity with differing motions. Langley has shown the possibility of taking advantage of the gustiness of the wind when soaring. Attention is called to the fact that the horizontal motion of an aeroplane greatly increases the pressure beneath it when falling, tending thus to sustain it effectively. On this fact depends the possibility of flight. The sustaining pressure is also reinforced by an important complementary suction above, with similar effect in supporting the falling mass. Artificial flight is a question of speed of horizontal motion; no man can raise himself from the ground by any mechanism operated by muscular power except with preliminary acceleration in the horizontal direction. Lord Rayleigh is inclined to agree with Sir Hiram Maxim that the problem of artificial flight is mainly one of time and money. It would presumably be mainly a military problem. He does not think it will prove a safe method of conveyance; but, as Maxim has remarked, we have not yet succeeded in making war quite safe.

The Hon. Charles A. Parsons, in the second paper, discusses motive power and the steam turbine. He commences with a paraphrase of a page in the introductory section of Thurston's 'History of the Steam Engine,' in which the account of the steam turbine in Hero's 'Spiritalia' is presented and goes on to say that an experiment made years ago in the production of a redesigned Hero engine enabled him to obtain twenty horse-power on a consumption of but forty pounds of steam per horse-power-hour, which is a very fair performance for engines of the simpler modern forms and of similar power. A later model illustrated his system of compounding but without commensurate advantage.

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Branca's turbine of 1629, similar in description and general construction to the impact water wheel, had been reproduced successfully by de Laval and is in extensive use in a form illustrating modern scientific construction. In 1884, Mr. Parsons began his work on his now familiar form of compound turbine, adopting the type of wheel known in hydraulics as the impact turbine. This proved practically successful, ultimately, and is now made in large numbers for electric 'plants.' It has been proved to be capable of as high economy as the reciprocating engines of the best modern constructors.

In 1894, the same plan was adopted for engines supplied to the *Turbinia*. The outcome was the redesigning of the screw propellor and its method of application and the attainment of a higher speed than had ever before been recorded, 32¾ knots, 38 miles, an hour. The steam consumption was 14½ pounds per horse-power-hour, a result better than was usually obtained in similar craft with even triple-expansion engines and under similar conditions of steam supply. About 28 pounds of steam were vaporized per square foot of heating surface of boilers.

The *Viper* and the *Cobra* have been later built on the same general plan and the former became the record-breaking vessel for the world, attaining above forty miles an hour (37.118 knots, 43 miles) on the dimensions of the regular 30-knot torpedo boat destroyer, a length of 210 feet, a beam of 21 feet and with 350 tons displacement. Water tube, safety boilers were fitted and the engines were of the compound turbine type.

A design for a war vessel is hypothetically proposed on this plan and Mr. Parsons considers it possible to build a ship of 420 feet length, 42 feet beam and 14 feet draught, having 2,800 tons displacement which should develop *eighty thousand* horse-power and a speed of 44 knots (over 51 miles) an hour. This represents a concentration of power never before dreamed of by the engineer, far less attempted or approximated, although an American designer, Mr. Mosher, has rivalled the work of Parsons in smaller craft.

Papers by Professor Ewing on the "Structure of Metals" and Sig. Marconi on wireless telegraphy fall into the same general category of work in applied science, and those of Lord Kelvin, Professor Dewar and others are in the field of pure science and have special interest through their promish of later utilization. Sir Andrew Nobel presents a remarkable and illuminating discussion on the modern explosives.—*Science.*

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THE AMERICANIZATION OF ENGLAND.

There is a field in which American influence is more marked, perhaps, than in any of those that have been already mentioned, and that is the domain of education. In the study of the classics and the liberal arts England, of course, has nothing to learn from America; but in technical and commercial instruction she is gaining valuable lessons from this side of the water. It is significant of the opinion in which the work of some of our great technical and scientific schools has come to be held, that on the foundation of the new Birmingham University a committee was sent over to the United States to study the methods of instruction in commercial branches with a view to including similiar courses in the institutions under their charge.

The whole idea of technical and commercial education in Great Britain may, perhaps, be ascribed to American influence. Until the force of American competition began to be felt very decidedly, and the successes of American trained engineers and commercial men in every part of the United Kingdom pointed to a moral too obvious to be disregarded, there was little demand and less provision for such practical training as the leading American universities have been engaged in giving for many years past. At the time when the Birmingham University was projected, it was openly announced that the chief object sought in its foundation was to afford British young men an opportunity to acquire the kind of training that is imparted in this country by such institutions as the Sibley College of Engineering at Cornell. Englishmen are coming around to the American view which regards the various technical and commercial pursuits as being as creditable as the callings traditionally known as the learned professions.

As an additional example of the growing respect in which the American style of practical education is coming to be held in England may be cited the increasing number of young Britons who are sent to the United States to obtain their education. Within the past year, also, a number of young Englishmen have been put into shops in Pittsburg and elsewhere in the United States as the best means of giving them a thorough practical knowledge of the best methods of factory management and of the trades with which they are to become identified in one capacity or another. All these young men will return home thoroughly imbued with American ideas, and will add increasing strength to the movement already proceeding toward the Americanization of British industrial life.—EARL MAYO, in *Forum*.

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THE SIBLEY JOURNAL OF ENGINEERING.

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THE SIBLEY JOURNAL OF ENGINEERING,
ITHACA, N. Y.

Our frontispiece this month depicts the Parsons steam-turbine generating set presented to Sibley College a year ago by the Westinghouse Machine Company, who hold the American rights to the Parsons patents. The full normal speed is about 4800 r.p.m., giving 80 cycles from the two pole alternator, and a voltage of 1100. The usual speed is about 4400, corresponding with 1050 volts. The machine, which is rated at 150 kw., is shown as rigged for a thesis test.

It is far better for the technical schools not to attempt to teach practice. Let them rather concentrate their efforts upon theory, as they have not the facilities to teach practice, and as it is changed before it is taught. There is more than enough theory to occupy their time, and the majority will never learn it if not taught at the schools. They cannot get too much. At the end of the course, upon passing satisfactory examinations, give the

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graduate a scientific degree. For they are not engineers, and no school can ever make them such. When they have had at least five years' experience with practical work, and upon writing a satisfactory dissertation on some theoretical or practical engineering subject, then let them receive their engineering degrees.—Alex. Rice McKim in *Engineering News.*

Commenting on this, *Machinery* says :

"Quite right. Engineering schools cannot teach practice, and the degree of 'engineer' loses its significance by being bestowed upon young graduates who are not in any sense engineers. Give the boys their fill of theory, for they will not have time for it afterward ; but if with this they could be impressed with the fact that practice can be learned only in actual commercial work, and that they will not become engineers until they have acquired such experience, a great step in advance would be gained in technical education."

Should this policy be adopted, how many would receive the degree of "Mechanical Engineer," to which their later attainments would unquestionably entitle them ? The degree itself is a certificate, from the technical school, to the effect that the recipient has successfully followed a certain line of study to completion ; said study fitting him to take his place among the workers in the engineering field, with every prospect of soon becoming a practical engineer. It is a self-evident fact that a practical engineer he is not, and can not be, upon leaving college ; but is that any reason for giving him some *other* degree, not at all indicative of the work or training he has had, rather than the one which signifies that he has the necessary theoretical foundation, and is now prepared to acquire the practical ? Is he not as much an engineer as is the graduated medical student a doctor ? And yet we do not hear any call for the latter to receive, not an "M.D." but a "B.S." The law student receives his "LL.B.," but most of them are lawyers' clerks for several years after obtaining it.

It seems to us that our contemporaries are taking an erroneous view of this matter. The graduated engineering student is as much of an engineer as a college course can ever make him, and the degree is essentially a collegiate one ; it bears the same relation to the student's technical training as the stamp on the eagle does to the gold contained in it ; it brands him as having passed the test and the requirements of the college of which he becomes an alumnus, and as such it should be understood.

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Department Notes.

Mr. H. L. Hepburn, '97, instructor in Experimental Engineering, is the author of an article in *Power*, "The Transfer of Heat from Steam to Water through a Partition." This has just been republished in pamphlet form by the Taunton Locomotive Works, with whom Mr. Hepburn was connected, prior to his call to Sibley.

Mr. Sanford A. Moss, instructor in Machine Design, is responsible for a well-considered article in the *American Machinist* for March 27th, 1902, on "Finish Directions on Drawings." His system does away with ordinary shade lines, which are now rarely used on commercial work, and uses a series of heavy lines to designate all surfaces which are to be finished. The "f" is thus omitted. Another item consists in encircling all machinist's dimensions, thus causing them to stand out clearly from the mass of pattern dimensions always used.

The "*Bulletin Scientifique*" of the University of Liége, March, 1902, contains a translation in abstract of Professor Durand's article in the SIBLEY JOURNAL, January, 1902, on the arrangement of the apparatus for determining the resistance of ships at the hydraulic laboratory on Fall Creek. The translator, M. le Professeur V. Dwelshauvers-Dery, concludes: "This hydraulic laboratory at Ithaca is undoubtedly the largest and best-equipped in existence" and "cannot fail to contribute greatly to the advancement of science as have the other laboratories at Ithaca". He adds:

"*On voit par là à quels résultats grands et utiles on arrive lorsque ceux qui ont la charge des intérêsts d'une école, et en même temps la puissance, n'ont pas les mains liées par les entraves de la routine ou des considérations étrangères.*"

Dr. Thurston is invited to visit Belfast, Ireland, in September next, as the guest of the British Association for Advancement of Science, of which he has been a corresponding member for many years. The purposes of the society are declared to be: "(1) To give impulse and direction to scientific inquiry; (2) To promote intercourse among students of Science; (3) To obtain a more general attention to the objects of Science," etc. The last

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meeting at Belfast was under the presidency of Professor John Tyndall, in 1874. The Local Committee states that Belfast is now a city of 350,000 people, population having doubled, very nearly, in the interval since the last meeting there. Its industries are linen manufactures, ship construction, steam-engine building, etc. The surrounding country contains many objects of interest, scientific, antiquarian and historic. The guests of the Association will be entertained by leading citizens of Belfast. The sessions will be held at Queen's College.

Professor R. C. Carpenter is the author of a discussion in the April *Power* on the disastrous boiler explosion which occurred at the Penberthy Injector Company's works in Detroit, last November. A large number of cuts accompany the article, which describes tests made on specimens taken from the fractured plates. Twelve of these tests were made in Sibley College, and all but one (59,599) showed a maximum strength per square inch of over 60,000 pounds. Nine showed an elongation of 14 % or upwards, but only one reached the 27 % required by the American Boiler Manufacturers' Association. The elastic limit was reached at from 22,500 to 34,000 pounds per square inch. In only six cases of the twelve did it reach one-half the ultimate strength, as required by the Association. In all cases both sulphur and phosphorus were excessive.

Our Minister to Berlin, Dr. Andrew D. White, ex-president of Cornell University, sends Dr. Thurston the program of the next meeting of the "Schiffbautechnischen Gesellschaft," to be held at Düsseldorf, June 2–5, and suggests his attending its sessions. He thinks it likely to prove interesting and probably also useful to the University. The opportunity is thought a remarkable one in many ways. Many great establishments are to be thrown open to the association, including Krupp's and perhaps others which are commonly strictly barred against individual visitors. Mr. White had been delighted with Dr. Durand's paper on the preparations made at Cornell for Sibley College work in research in marine engineering, in the hydraulic laboratory and its great canal, and he had found the paper very thoroughly appreciated by friends at Berlin, familiar with the general subject, to whom he had shown it. At the date of his letter he was on the point of starting for the Riviera for a vacation of a few weeks.

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Mr. Henry H. Norris, of the Department of Electrical Engineering, has a very extended and complete article in the issue of February, 1902, of *The Current Cyclopedia*, on Electric Automobiles. Prof. Norris describes their construction, their uses, their limitations and their promise. He considers that these vehicles have already been reasonably successful, and they are sure to come into extensive use after a little, when their present limitations of weight and cost and restricted range and radius of action shall have been more or less completely removed by further invention and improvement, mainly in the reduction of weight of the storage batteries which are carried by them. Electric omnibusses and cabs as well as pleasure carriages have been in use for a number of years, and often with commercial success. Where they have failed, it has usually been through defective business management rather from scientific or mechanical deficiencies. Its advantages, within its limits, are its simplicity and ease of repair, its perfection of control, its noiselessness, its safety from fire or explosion, its overload capacity and its efficiency.

SUPERPOSED ELECTRIC CURRENTS.—A patent dated March 18, 1902, issued to Dr. Frederick Bedell, describes apparatus to be employed in a system involving the transmission of both direct and alternating currents over the same line conductors, and the utilizing of either the direct or alternating current, as may be desired. In a previous patent issued to the same inventor it is shown that there is a less line loss for a given amount of energy carried, if an alternating current is superposed on a direct current, and this patent relates to means for utilizing at a receiving point, either the direct or the alternating current, or both, as may be desired. When such a system is employed it is obvious that the line wires will carry alternating or direct current according to the demands of the translating devices connected thereto, the resultant line current being variable and unsymmetrical in reference to the zero line, and so be either a direct or an alternating current according to the predominence of one current or the other. At the direct current receiving devices choking coils are included having a high self-induction, which will readily permit the passage of the direct current, but will effectually shut off the alternating current. The device for receiving alternating currents to the exclusion of direct currents, consists of a transformer in connection with condensers; or if condensers are not used, high resistance may be inserted in the primary, which may be made so high that

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only a negligible amount of direct current will flow. To avoid the effect of any direct current that may flow through the primary, the core should contain an amount of iron corresponding to the value of the direct current component of the current plus the amount corresponding to the alternating current. A description is also given of a rotary converter adapted to be operated in connection with the present system.

—*Electrical World and Engineer.*

Personals.

'89. Bion Joseph Arnold, E.E., has been selected by the New York Central Railroad Company, to design a feasible system for electrically operating its trains (about 600 per day) into and out of New York. This, together with his recent notable work in connection with electric railway developments, has made him one of the most prominent figures in the field of electrical engineering.

'95. David B. Rushmore, E.E., is in the employment of the Stanley Electric Company, at Pittsfield, Mass.

'98. John Hancock Wynne, M.E., is rejoicing over the advent of an heir.

'99. John S. Avery, E.E., Editor-in-Chief of the 1898-99 SIBLEY JOURNAL is with the Heine Safety Water-Tube Boiler Company, with headquarters at St. Louis, Mo.

'99. Mather W. Sherwood, M.E., of the 1898-99 SIBLEY JOURNAL Board is with the Imperial Engine Co., of Painted Post, N. Y.

'00. Herbert A. Wiltse, M.E., is located at Allentown, Pa., in the employment of the Atlas Portland Cement Company of that place.

'01. Clifton B. English, M.E., who is with the Atlas Portland Cement Company of Easton, Pa., is the proud possessor of an heir of the feminine persuasion.

'01. Frederick J. Folk, E.E., Business Manager of the 1900–1901 SIBLEY JOURNAL, having left the General Electric Company, with whom he has been employed since April, 1901, has a position with the New York and Queens Electric Light and Power Company, with headquarters at Astoria, Long Island.

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The *Street Railway Journal*, of March 1st, publishes an extended and finely illustrated account of the Camps Bay, Capetown and Sea Point Electric Tramway, which has as superintendent, Mr. Chester P. Wilson, Cornell, M.E., '92, MM.E., '96.

At the recent commencement of the University of the Cape of Good Hope, three graduates of American colleges were "admitted to degrees." Among them was William McDonald, M.Sc., Cornell.

BOOK REVIEWS.

La Mécanique à l'Exposition de 1900. Published under the patronage and technical direction of a committee of editors, under the presidency of M. Haton de la Goupillière, inspector general of the mines. Vve. Ch. Dunod, publisher, Paris, 1901. Price of the entire collection, some 20 numbers, 60 francs.

The sixteenth number (tenth in order of appearance), has just been issued. It is devoted to "Automobiles and Cycles," and is written by Paul Sencier. There are 52 large pages (8½ x 12) and 72 illustrations. The first section is taken up by an elaborate and well illustrated and detailed discussion of three gasoline automobiles (de Dion Bouton, Darracq, and Gaillardet), and two electric vehicles (Jeantaud and Kriéger). In the second portion are described various features of the bicycle exhibit, with particular reference to such details as hub-coaster-brakes, and speed-changing devices.

L'Électricité à l'Exposition de 1900. Published with the assistance and under the technical direction of MM. E. Hospitalier, editor-in-chief of *l'Industrie électrique*, and J.-A. Montpellier, editor-in-chief of *l'Électricien*, with the aid of engineers and industrial electricians. Vve. Ch. Dunod, publisher, Paris, 1902. Price of the entire collection, some 15 numbers, 50 francs.

The fourteenth number (tenth in the order of appearance) has just been issued. "Electric Registers" or "Meters" is the subject here treated by MM. Montpellier and Aliamet. The matter is divided into four sections:—Time registers, Quantity registers, Registers of electrical energy, and Special registers. The third receives deservedly the greater amount of attention, being devoted to motor- and oscillating-registers and "discontinuous" integrating registers. Electrodynamic wattmeters, and motor-registers based upon the Ferraris principle of revolving fields are here discussed at some length, the Elihu Thompson continuous wattmeter being prominently mentioned. The 60 large pages contain 86 illustrations.

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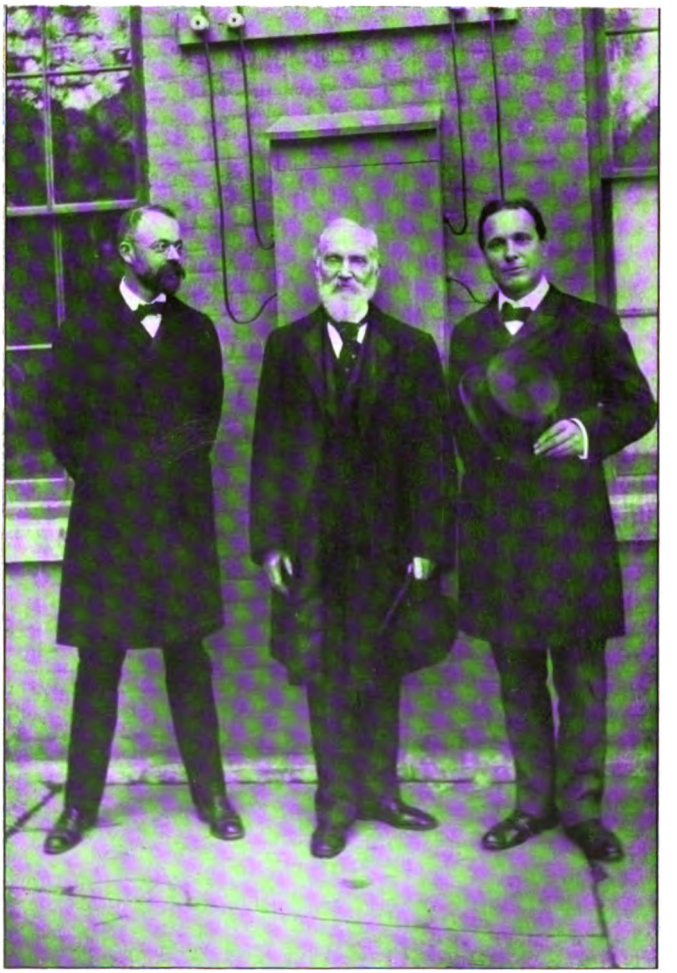

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THE SIBLEY JOURNAL OF ENGINEERING.

VOL. XVI. MAY, 1902. No. 8.

IN CORNELL UNIVERSITY.

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislature of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

LORD KELVIN.

Lord Kelvin, who was recently the honored guest of the University, was born in Belfast, Ireland, in 1824. He was the son of James Thomson, a well known mathematician, who was appointed Professor of Mathematics in the University of Glasgow in 1832. William Thomson entered that university at an unusually early age and distinguished himself as an undergraduate by his ability in mathematics. In 1839 he entered the University of Cambridge, England, where he was graduated in 1845 with the highest mathematical honors. The following year he was appointed Professor of Natural Philosophy in the University of Glasgow, which position he held until 1899, when he retired, after fifty-three years of service, to be succeeded by his old pupil and assistant, Professor Andrew Gray.

Thomson's earlier work was largely mathematical in its character and it was through his contributions to the Theories of Electricity and to Thermo-dynamics, that his extraordinary powers were first manifested. In the early fifties he began to interest himself in the numerous problems upon which the success

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of submarine telegraphy depended and when the project of laying a cable across the Atlantic began to be seriously considered, he became the electrician of the company. From 1854, in which year he published the law which expresses the effect of distributed capacity of cables upon the rate of transmission, until 1870, when his siphon recorder superceded all other instruments as the most suitable apparatus for the receiving of cable messages, much of his time was devoted to the application of physics to submarine telegraphy. In 1866, when the first permanent cable across the Atlantic was completed, his labors were publicly recognized by the conferring upon him of the Order of Knighthood.

Thomson's extended service upon cable ships naturally caused his attention to be drawn to problems relating to navigation and particularly to the necessity of a compass which could be used upon iron ships. His compass, in which the magnetic disturbances of the ship itself are very accurately compensated for by soft iron in the neighborhood of the needle, has been found to afford the only adequate means for the successful use of this instrument on vessels constructed of steel or iron.

In spite of the arduous character of his services to the cable companies and the time devoted to the devising and development of the long series of electrical instruments which we owe to his ingenuity, Thomson has been one of the most prolific writers on theoretical physics of our time, and of the three hundred and more papers from his pen, an extraordinary proportion have that fundamental character which alone gives permanent value. About the year 1879 he entered in collaboration with the late Professor Tait, of Edinburgh, upon the preparation of a treatise on Natural Philosophy in which the term was used in the sense in which Newton employed it, "to denote the investigation of laws in the material world, and the deduction of results indirectly observed." The object of this work was two fold: "To give a tolerably complete account of what is now known of natural philosophy in language adapted to the non-mathematical reader, and to furnish to those who have the privilege which high mathematical requirements confer a connected outline of the analytical processes by which the greater part of that knowledge has been extended into regions as yet unexplored by experiment." It was the ambitious intention of the authors to base this great work throughout upon the principle of the conservation of energy. The work never reached completion, but the two volumes which were published, and which are devoted

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entirely to the preliminary principles of kinematics and dynamics and to statics, form in themselves one of the most exhaustive and important treatises on a mathematical subject ever produced in our language. Twenty years, or such part thereof as they had been able to give, had been spent upon this introductory part alone; and in the preface to the second volume the authors definitely announced the abandonment of the attempt to complete their work. In 1882, Thomson began the republication in collected form of his mathematical and physical papers, of which, up to 1890, three volumes had appeared.

The almost unparalleled achievements of William Thomson have in these last years been recognized in every way in which it is in the power of the world of science to express itself. Degrees and distinctions have been showered upon him. In 1891 he was made President of the Royal Society, and was raised to the peerage of Great Britain under the title of Lord Kelvin. In him the world has witnessed the extraordinary phenomenom of a man capable of following throughout a long life three distinct careers with a degree of success in each scarcely equalled by any of his contemporaries. He is an electrical engineer of the first rank, an inventor whose instruments, such as the absolute electrometer, the quadrant electrometer, the mirror galvanometer, the siphon recorder, the electrostatic voltmeter, the current balance, the apparatus for deep sea sounding, and the compensated compass, form a class by themselves. They are a concrete embodiment of the complete mastery of the mind that devised them and the principles upon which they depend. They express in a way that could not be done by words the power of the inventor to fulfill in the most perfect and simple manner the conditions of satisfactory and accurate performance. Finally, and more important than these, because more rare, we have Kelvin's lifelong activity as a theoretical physicist. To be able to really contribute something to the world's knowledge in this field is given to but few. Years ago it was said of Helmholtz that he was the first mathematician, the first physiologist and the first physicist of Europe. It may with equal truth be said to-day of Lord Kelvin that he is the foremost electrical engineer, inventor and physicist of the English speaking world.

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A DISCUSSION OF LEDOUX' & UNWIN'S FORMULAE FOR THE FLOW OF AIR IN PIPES, WITH SPECIAL REFERENCE TO HEATING AND VENTILATING.

H. DIEDERICHS.

In computing sizes of pipe required to carry certain quantities of air in a given time at known pressure and temperature, either in case of compressed air or in case of air used for heating and ventilating, there are two formulae which may be employed for the purpose. The first one of these is due to Ledoux, and is derived by him from a set of experiments reported in the *Annales des Mines* for 1892. The second one may be derived from an expression given by Unwin for the velocity of flow. (*Ency. Brit.* Vol. 12, Hydromechanics.)

Ledoux gives the following:

$$D = .1589 \sqrt[5]{\frac{q^2 L T}{T_0^2 \left(1 - \frac{p^2}{p_0^2}\right)}}$$

where D = Diameter of pipe in meters,

q = Cubic metres of air per second, at inlet pressure,

L = Length of pipe in metres,

T and T_0 are absolute temperatures, °C, at outlet and inlet respectively, and p_0 and p are absolute pressures at inlet and outlet of pipe respectively, expressed in any convenient units.

This formula in English units becomes

$$d = .0217 \sqrt[5]{\frac{q^2 l t}{t_0^2 \left(1 - \frac{p^2}{p_0^2}\right)}}$$

where d = Diameter in feet,

q = Cubic feet per minute, at inlet pressure,

l = Length in feet,

t and t_0 are absolute temperatures, °F. at outlet and inlet, and p and p_0, as above.

Unwin gives for the velocity of air in a pipe

$$u = \sqrt{\frac{g\, t'\, d'\, c}{4\, \epsilon\, l}\left(1 - \frac{p^2}{p_0^2}\right)}$$

where u = initial velocity in feet per second,

g = 32.16,

t' = absolute mean temperature of air,

d' = diameter of pipe in feet,

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$c = 53.15$ for air,
$l =$ length in feet,
$\epsilon =$ coefficient of friction.

From this the velocity in feet per minute $= 60\,u$, and if d' be the diameter of the pipe, the quantity of air flowing per minute will be

$$q = \frac{\pi d'^2}{4} \times 60 \sqrt{\frac{g\,t'\,d'\,c}{4\,\epsilon\,l}\left(1 - \frac{p^2}{p_0^2}\right)}$$

$$= 47.12 \sqrt{\frac{g\,t'\,d'^5\,c}{4\,\epsilon\,l}\left(1 - \frac{p^2}{p_0^2}\right)}$$

where $q =$ cubic feet of air, at inlet pressure,

Solving for d',

$$d' = \sqrt[5]{\frac{4\,q^2\,l\,\epsilon}{(47.12)^2\,g\,c\,t'\left(1 - \frac{p^2}{p_0^2}\right)}}$$

To show the agreement between the two expressions, put

$$\frac{d}{d'} = \frac{.0217 \sqrt[5]{\frac{q^2\,l\,t}{t_0^2\left(1 - \frac{p^2}{p_0^2}\right)}}}{\sqrt[5]{\frac{4\,q^2\,l\,\epsilon}{(47.12)^2\,g\,c\,t'\left(1 - \frac{p^2}{p_0^2}\right)}}} = .0217 \sqrt[5]{\frac{(47.12)^2\,g\,c\,t\,t'}{4\,t_0^2\,\epsilon}}$$

$$= \sqrt[5]{\frac{.0046\,t\,t'}{t_0^2\,\epsilon}}$$

Now as regards the values of t, t', t_0, it has been found by experiment that the loss of temperature between the ends of the pipe is less than that caused by adiabatic expansion from p_0 to p. This is presumably due to the fact that whatever work is done by air in overcoming friction must reappear as heat in the air itself. In any case, even with adiabatic expansion, unless the loss of pressure is large from one end of the pipe to the other, the loss of temperature is not great. It may be assumed, then, in any practical case, that t, t', and t_0 are not very different, and that we may put without great error

$$t\,t' = t_0^2.$$

With this assumption our expression for ratio of diameters becomes

$$\frac{d}{d'} = \sqrt[5]{\frac{.0046}{\epsilon}}$$

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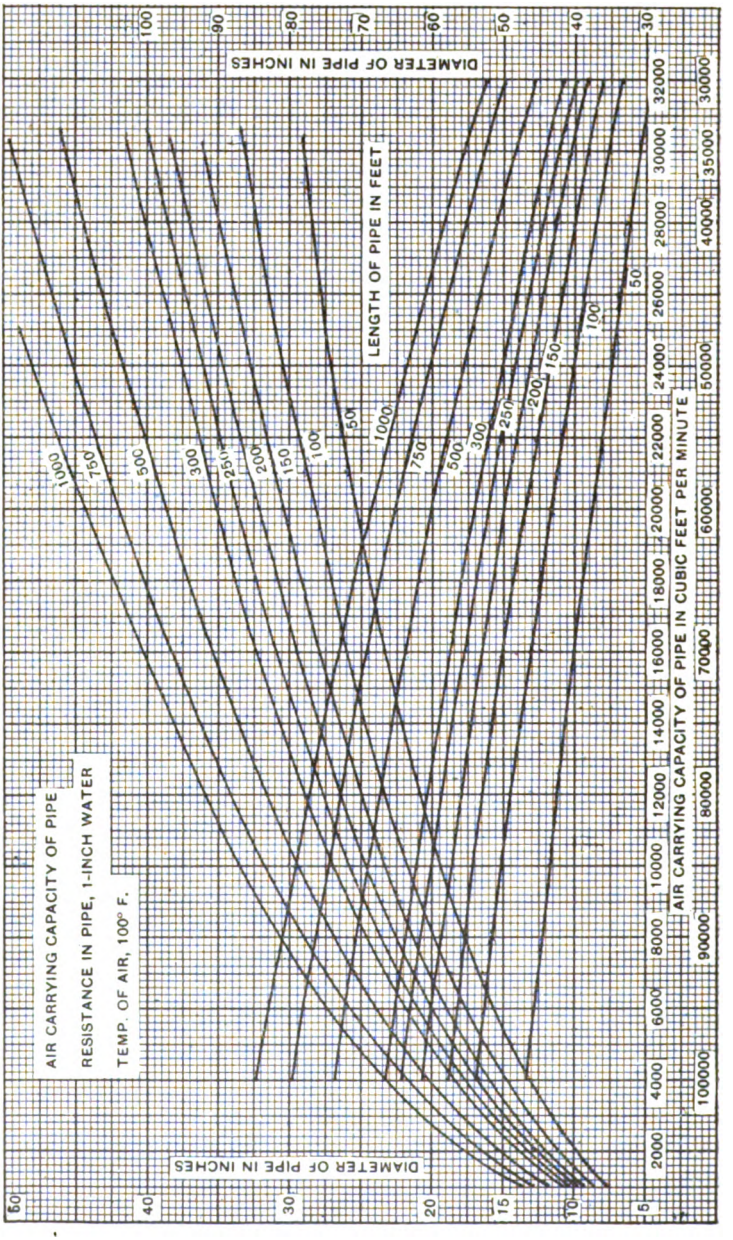

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This shows that if $\epsilon = .0046$, the formulae are identical. Or, in other words, Ledoux has assumed ϵ as constant, while Unwin varies it according to circumstances. The circumstances affecting ϵ are the condition of the pipe, its diameter, and the velocity of flow.

Ledoux' formula has the advantage that ϵ does not enter the calculation, and if it is decided to employ this formula, it becomes interesting to see how the assumption of ϵ as constant affects the results.

Experiments seem to show that at a velocity of about 100 feet per second, ϵ may be expressed by the formula

$$\epsilon = x\left(1 + \frac{3}{10\,d}\right)$$

where x is a constant depending on the condition of the surface in the pipe, and d is the diameter in feet.

For cast iron pipe it was found that

$$\epsilon = .005\left(1 + \frac{3}{10\,d}\right)$$

while some experiments made by M. Stockalper at the St. Gothard tunnel, gave, for somewhat smoother pipe,

$$\epsilon = .0028\left(1 + \frac{3}{10\,d}\right)$$

Let us assume, for purposes of comparison, that

$$\epsilon = .003\left(1 + \frac{3}{10\,d}\right)$$

and it is quite probable that the coefficients from this expression are not far in error for velocities somewhat greater or less than 100 feet per second.

Then assuming a number or values of d in feet, the values of ϵ and d' may be computed from the expressions given above.

d feet.	ϵ	d'	$\frac{d}{d'}$
.2	.00750	.22	.907
.6	.00450	.60	1.004
1.0	.00390	.97	1.034
2.0	.00345	1.89	1.059
3.0	.00330	2.81	1.068
4.0	.00323	3.73	1.073
5.0	.00318	4.64	1.077
6.0	.00315	5.56	1.079

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The last column of the table shows the variation in the results from the formulae. It shows that for small sizes, below .6 feet, Unwin's expression gives higher results than that of Ledoux, the excess amounting to a little over 9% for a $2\frac{1}{2}''$ pipe. For sizes above .6 feet, Ledoux' formula gives the higher results, the excess being about 8% when the size of the pipe has reached 6 feet.

Applying this discussion to the case of heating and ventilating, it is not very often that a hot air or vent duct is below .6 feet in diameter, and in computing sizes of ducts Ledoux' formula may be used. It will give results somewhat too large, but this is if anything an advantage, and it possesses the further advantage that no constantly varying coefficient of friction need be assumed.

The appended table shows the diameter of pipe required to carry certain quantities of air through certain lengths of pipe. In these computations an average case in heating has been assumed. Taking p as 14.7 lbs. absolute, and assuming that the drop in pressure shall not exceed 1" water, $p_0 = 14.736$ lbs.

Assuming t_0 as 100° F. absolute, t may be computed from the formula

$$\frac{p_0}{p} = \left(\frac{t_0}{t}\right)^{3.45}$$

if adiabatic flow be assumed. From this $t = 560.4°$ F. Or the expansion may be considered isothermal without great error, in which case $t = 561$. In these computations $t = 560.4°$ F.

Substituting these figures, the formula

$$d = .0217 \sqrt[5]{\frac{q^2 l t^2}{t_0^2 \left(1 - \frac{p^2}{p_0^2}\right)}}$$

becomes $$d = .0177 \sqrt[5]{q^2 l}$$

or d in inches $= .212 \sqrt[5]{q^2 l}$, from which the table has been computed. For any other temperatures than those used for the table, *divide* the results of the table by

$$\sqrt[5]{\frac{.0018\, T_0^2}{T}}$$

where T_0 and T are the absolute temperatures at inlet and outlet respectively.

For any other pressures, *divide* results of the table by

$$\sqrt[5]{\frac{P_0^2 - P^2}{.005\, P_0^2}}$$

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CUBIC FEET OF AIR PER MINUTE	LENGTH OF PIPE IN FEET																	
	50		100		150		200		250		300		500		750		1000	
	D DIAMETER OF PIPE IN INCHES												A SIDE OF SQUARE PIPE IN INCHES					
	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A
1000	7.25	6.6	8.50	7.7	9.25	8.4	9.75	8.9	10.25	9.3	10.50	9.5	11.75	10.7	12.75	11.6	13.50	12.3
2000	9.75	8.9	11.25	10.2	12.25	11.1	13.	11.8	13.25	12.3	14.	12.7	15.50	14.1	16.75	15.2	17.75	16.1
3000	11.50	10.4	13.25	12.	14.25	12.9	15.	13.6	15.75	14.3	16.50	15.	18.	16.3	19.50	17.7	20.75	18.8
4000	12.75	11.6	14.75	13.4	16.	14.5	17.	15.4	17.75	16.1	18.50	16.8	20.25	18.4	22.	20.	23.25	21.1
5000	14.	12.7	16.25	14.7	17.50	15.9	18.50	16.8	19.25	17.5	20.	19.2	22.25	20.2	24.	21.8	25.50	23.1
10000	18.50	16.8	21.25	19.3	23.	20.9	24.50	22.2	25.50	23.1	26.25	23.8	29.25	26.6	31.75	28.8	33.75	30.6
20000	25.50	23.1	28.	25.4	30.50	27.6	32.25	29.2	33.75	30.6	35.	31.8	38.75	35.2	42.	38.1	44.50	40.4
30000	28.75	25.	33.	30.	35.75	32.5	38.	34.5	39.50	35.9	41.	37.2	45.50	41.4	49.25	44.7	52.25	47.3
40000	32.50	29.5	37.	33.6	40.	35.3	42.50	38.6	44.50	40.4	46.	41.8	51.	46.3	55.25	50.2	58.50	53.1
50000	35.25	32.	40.50	36.7	43.75	39.7	46.50	42.3	48.50	44.1	50.25	45.7	55.75	50.7	60.25	55.	64.	58.2
75000	41.25	37.6	47.50	43.2	51.50	46.8	54.50	49.6	57.	51.8	59.25	53.8	65.50	59.6	71.	64.5	75.25	68.3
100000	46.50	42.2	53.25	48.3	57.75	52.3	61.25	55.7	64.	58.1	66.50	60.3	73.50	66.7	79.75	72.3	84.50	76.7
125000	50.75	46.	58.25	52.8	63.25	57.3	67.	60.8	70.	63.5	72.50	65.8	80.50	73.	87.25	79.1	92.50	83.9
150000	54.50	49.4	63.75	56.9	68.	61.7	72.	65.3	75.25	68.3	78.	70.8	86.50	78.5	93.75	85.	99.25	90.
175000	58.	52.6	66.75	60.7	72.25	65.5	76.50	69.4	80.	72.6	83.	75.3	92.	83.5	99.75	90.5	105.75	96.
200000	61.25	55.6	70.25	63.7	76.25	69.1	80.75	73.2	84.25	76.7	87.25	79.4	96.75	87.7	105.25	95.6	111.50	101.2

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where P_0 and P are the absolute pressures at inlet and outlet. From the table curves have been constructed which show at a glance the diameter of pipe required to carry quantities of air varying from 1,000 to 100,000 cu. ft. per minute under the assumed conditions of pressure and temperature. Conversely, if the diameter be known, the carrying capacity may be found.

CASE OF RECTANGULAR DUCT.

It is not very often that a circular duct is used in heating and ventilating. They are nearly always rectangular in shape. For the same cross-sectional area a rectangular pipe will convey less air under the same conditions than a round one, owing to slightly greater frictional resistances. A correction usually made in such case is to consider a square pipe the equivalent in carrying capacity of an inscribed round one. There is no doubt, however, that this allowance is greatly in excess in case of a short pipe, and is probably too great in any case.

The method of determining the size of a rectangular duct would be to first determine the required diameter of a round pipe to do the same work, and then to employ a formula expressing the relation between this diameter and the sides of a rectangular duct.

To get such a formula, Unwin's expression for the velocity of flow may be conveniently employed, because it involves the hydraulic radius of the pipe, *i. e.*, the ratio of area to perimeter.

We have for a round pipe, where q = capacity,

$$q = \frac{\pi d^2}{4}\sqrt{\frac{g\,t\,c\,m}{\epsilon\,l}\left(1-\frac{p^2}{p_0^2}\right)}$$

For a rectangular duct of same length with a and b as sides:

$$q = a\,b\sqrt{\frac{g\,t\,c\,m'}{\epsilon'\,l}\left(1-\frac{p^2}{p_0^2}\right)}$$

Where m and m' are the mean hydraulic radii.

For equal capacity under the same conditions of pressure and temperature, we must have,

$$\frac{\pi d^2}{4}\sqrt{\frac{m}{\epsilon}} = a\,b\sqrt{\frac{m'}{\epsilon'}}$$

Now it was above shown that for ordinary sizes of pipe Ledoux was not greatly in error in assuming ϵ constant, and in this particular case the area $a\,b$ is not greatly different from $\frac{\pi d^2}{4}$, hence the velocity of flow can not be very greatly different in the

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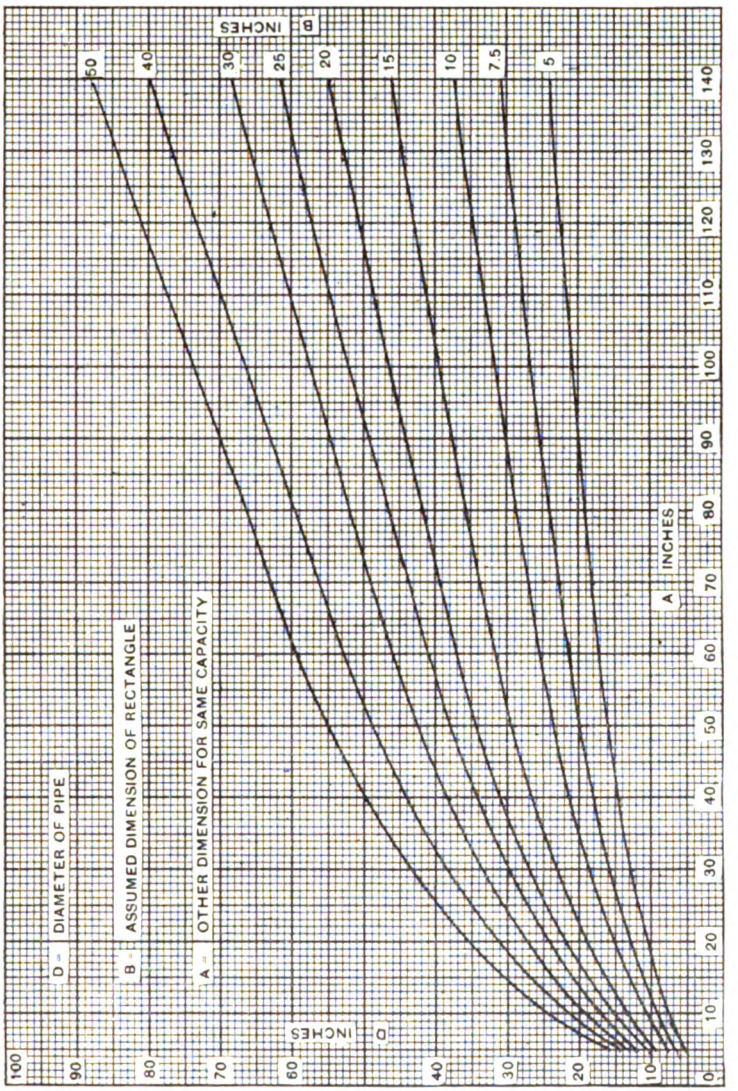

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two pipes. Both of these considerations would seem to show that ϵ may be taken equal to ϵ' without very great error.

We shall then have

$$\frac{\pi d^2}{4}\sqrt{m} = a\,b\,\sqrt{m'}$$

or

$$\frac{\pi d^2}{4}\sqrt{\frac{d}{4}} = a\,b\,\sqrt{\frac{a\,b}{2(a+b)}}$$

from which

$$\frac{\pi^2 d^5}{64} = \frac{a^3 b^3}{2(a+b)}$$

This may be reduced to

$$\frac{a^3 b^3}{a+b} = .308\,d^5$$

This equation is difficult of direct solution for either a or b, but with the aid of some assumptions, nearly every practical case may be covered.

In nearly all cases one of two things may be assumed. It is generally possible to determine one dimension of the rectangle, or the ratio between the sides may be assumed.

I. One side known.

In this case a graphical solution is the best means. The second set of curves show the relation between a and d when b is known. Let us assume, for instance, that a round pipe 40″ in diameter is required. Then, if b be assumed equal to 15″, follow the ordinate $d = 40$ to its intersection with the curve marked $b = 15$, when it is found that a must be 102.5″.

II. Ratio $\frac{a}{b}$ is known.

Assume $\frac{a}{b} = c$.

The formula then becomes $\frac{a^5}{c^2(c+1)} = .308\,d^5$

and $\qquad a = .79\,d\,\sqrt[5]{c^2(c+1)}$

From this a may be found, and finally b from $b = a \div c$.

Special case of square pipe.

In this case $a \div b = c = 1$, and we have

$$a = .79\,d\,\sqrt[5]{2} = .908\,d.$$

From this expression the second columns of the table are computed.

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THE PENBERTHY BOILER EXPLOSION.

R. C. CARPENTER.

The disastrous and fatal boiler explosion in the works of the Penberthy Injector Company of Detroit is remarkable as being one of the very few cases in which the cause of the explosion has been discovered.

The boiler in question was of the fire-tube type, 16 feet long, 5½ feet in diameter on the inside, and contained 94 4″ tubes. The shell was ⅜″ thick; heads ½″. The shell consisted of two longitudinal sheets, double-riveted in two seams extending the full length of the boiler. A dome 39″ high and of 39″ diameter was riveted on the top sheet. The steel called for in the specifications was required to have a tensile strength of 60,000 pounds per square inch, and the boiler was allowed a working pressure of 100 pounds per square inch. It was insured.

The strength of the plates along a longitudinal line parallel to a seam may be obtained from the formula

$$T=\frac{p\,D}{2t}$$

where T= tensile strength in pounds per square inch, p= steam pressure per gauge, D= internal diameter of shell, and t= thickness of shell. With the dimensions and pressure given, T figures out at 8,800 pounds per square inch, giving an apparent "factor of safety" of 6.81. Account must now be taken of the rivet holes, for the torn sheet was ruptured partly in the solid (?) metal, and partly along one line of rivets. The rivets were ¾″ diameter, in $\frac{13}{16}$″ holes, and spaced 3″ apart. Thus $\frac{13}{16} \div 3$ or 27.1% of the solid metal had been removed for the insertion of the rivets. This left 72.9% of the original strength of the plate, and would require an apparent tensile strength per square inch of 12080 pounds. This leaves a "factor of safety" of 4.96.

The shell was ruptured in the top sheet near the longitudinal seam on one side, and was thrown violently 30 or 40 feet towards the other side. The line of fracture was mostly away from the rivet holes, but its direction was not at all regular, and it passed through a number of rivet holes. The heads were partly separated from the shell, through the shearing of a portion of the connecting rivets. Many of the tubes retained their positions in the heads. Some of the braces were twisted off.

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To the loss of 30 lives as a result of the explosion is attributable the unusually careful investigation made by the authorities. The testimony showed the boiler to have been in excellent condition, with an abundant supply of water. Aside from the features of poor riveting and bracing, neither of which could have caused the explosion, it was found that the sheets were somewhat thinner than 3/8", the average thickness determined being not far from 1/3". Using 0.334" as a basis, Professor M. E. Cooley, who was engaged by the city attorney to investigate the cause of the disaster, calculated by the formula above given (Unwin's) that the bursting pressure should have been 487 pounds per square inch; with the designed thickness of metal, the corresponding pressure would have been 550 pounds.

Investigation showed the sheet near the point of rupture to have been exceedingly brittle, it being found possible to knock off pieces of the steel with a hammer. These showing no elongation or contraction of area, it was decided to cut off a series of test pieces from a point near the rupture, and determine the exact qualifications possessed by the steel. Some of these specimens were tested by Professor Cooley, and the rest in the mechanical laboratory of Sibley College. For a 9" length, the specimens were milled to a width of 1.2", giving a sectional area slightly in excess of 0.4 square inch.

The table shows the results obtained from those specimens which were tested in Sibley College. The first seven columns are made up of specimens taken from the ruptured sheet, near the point of rupture. Columns 27, 29, and 33 show results from test pieces taken from a portion of the boiler which did not experience any severe straining action. This was considered desirable because of the greatly diversified results obtaining at different portions of the ruptured plate. Columns X and XXX show the results from specimens taken from a similar, adjoining boiler, which did not explode, and was presumably in the same condition as that originally held by the exploded boiler.

In studying the table, it is well to bear in mind a portion of the specifications adopted by the American Boiler Manufacturers' Association as requirements for the steel in a boiler:

"Shell plates exposed to the direct heat of the fire or the gases of combustion, as in the external shells or heads of externally fired boilers, or plates in which any flanging is to be done, to have from 60,000 to 65,000 pounds tensile strength; elongation not less than 27 per cent in 8 inches; phosphorus not over .03

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TABLE.

SPECIMEN.	T_1	T_3	T_5	T_9	T_{11}	B_{17}	B_{19}	27	29	33	X	XXX
Thickness of Specimen	0.35	0.344	0.343	0.339	0.339	0.346	0.341	0.342	0.371	0.366	0.331	0.333
Width of Specimen	1.205	1.209	1.21	1.207	1.206	1.208	1.207	1 205	1.20	1.204	1.506	1.502
Area of Cross-Section	.4218	.4159	.4150	.4092	.4088	.4180	.4116	.4121	.4452	.4407	.4989	.4997
Elongation, per cent.	**16.5**	**16.62**	**15.0**	**8.12**	**8.8**	**14.0**	**11.87**	**19.62**	**20.37**	**18.50**	**27.25**	**26.25**
Reduction of Area, per cent.	**48.75**	**44.16**	**42 31**	**40.57**	**41.6**	**32.91**	**43.27**	**47.88**	**51 75**	**51.47**	**50.44**	**50.07**
Load per square inch, maximum	60798	61110	61517	64839	62964	64617	66375	60665	61184	60926	59599	60150
Load per square inch, elastic limit	32000	24000	27200	33600	32800	32400	34021	29200	29600	30800	22500	24000
Modulus of Elasticity*	29.76	29.09	28.63	30.55	29.55	26.66	29.92	28.91	28.19	28.50	29.80	28.91

* Millions of pounds.

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per cent, sulphur not over .025 per cent. For all plates the elastic limit to be at least one-half the ultimate strength."

It will be noticed that in very many cases, as mentioned in the April JOURNAL, page 305, the elastic limit failed to reach one-half the ultimate strength, as required, and in only one case did a test show an elongation of 27 per cent, this being a specimen from the boiler which did not explode. The only case in which an ultimate strength of 60,000 pounds was not reached was one from the unexploded boiler.

The effect of phosphorus in excess is to make the steel brittle when cold. The determinations of phosphorus showed values ranging from .073 per cent to .098 per cent, or about three times the quantity allowed by the specifications. This excess of phosphorus corresponds with the small percentage of elongation and reduction of area observed, and probably serves to explain the peculiar kind of fracture found in the exploded boiler. This fracture, it will be remembered, was in the lap of the riveted joint, very close to the rivets. The end of the sheet being firmly held by the rivets, it is probable that the internal vibration, due to variation in pressure and temperature, caused a motion, which, slight though it was, sufficed to bend the sheet backward and forward through a very small angle, around the riveted joint as an axis. The brittle metal was thus easily cracked, and this was not observed, as the rupture was in the lap of the joint. The crack must have been of very gradual formation, finally reaching such proportions that the pressure inside was sufficient to suddenly overcome the resisting force, and liberate the tremendous amount of energy stored in the heated water.

The projected area of the cylindrical portion of the boiler having been $16 \times 12 \times 66 = 12672$ square inches, and a pressure of 93 pounds gauge being maintained on the boiler at the time, it follows that the rupture force was 1,178,500 pounds, or 589 (net) tons. This tremendous force was continually prying at the weakest point of the shell until, overcoming the strength of the latter, the disaster occurred.

The combined steam and water space in the boiler was a little over 300 cubic feet, of which it may be assumed that 200 cubic feet were water and 100 cubic feet steam, at the time of the explosion. The temperature of the steam and water corresponding to a boiler pressure of 93 pounds, was 333° Fahrenheit. On being released, the water would at once fall to atmospheric pressure, with its corresponding temperature of 212°, and the heat due to a

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fall of 121° would be liberated. At 56.25 pounds per cubic foot, this would amount to 6,808 B.T.U. per cubic foot, or a total of 1,361,200 B.T.U.. The energy in the steam may be figured out at 84,000 B.T.U., giving a total of 1,445,200 B.T.U. At 778 foot pounds per B.T.U., this figure represents 562,000 foot-tons. This energy was applied practically instantaneously, and, being sufficient to lift the building several hundred feet from its foundation, were there no losses, the appalling extent of the disaster cannot occasion surprise. It is noteworthy that the energy per cubic foot of water was 2,650 foot-tons, while that per cubic foot of steam was only 320 foot-tons.

RAPID TELEGRAPHY.

GEORGE S. MACOMBER.

Various ways have been developed more or less successfully for increasing the word per minute capacity of telegraph lines, by duplex, quadruplex and multiplex telegraphy. One of the most successful systems of the last mentioned class was described in a lecture before Sibley College, April 11th, 1902, by Mr. Patrick B. Delany of South Orange, N. J.

Mr. Delany was born in Ireland in 1845 and came to America about twenty years later, where he began as a telegraph operator. In 1874 he received a patent for an improved telegraph relay and since that date has been granted about eighty patents in this country and nearly as many abroad.

In 1881 his attention was called to a synchronous movement for multiplex telegraphic apparatus which had been brought to this country by its inventer, Poul La Cour of Copenhagen, Denmark. After trying without success to make his invention operate satisfactorily, Mr. La Cour left the apparatus in New York and returned to his home.

Mr. Delany was requested to investigate the merits of the invention, by a friend in whose care it was left, but he felt that all time put upon such a scheme would be wasted, and hence declined. He was, however, induced to make an examination, and then succeeded in making the synchronous movement operate successfully for a short time. This brief operation raised his interest in, and appreciation of La Cour's invention and he decided to make a thorough investigation of its merits.

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This apparatus as described in La Cour's patent, consisted of two parts. First, A magnetized reed or tuning fork, and a pair of electro magnets so arranged that the fork or reed would be kept in vibration by the electromagnets and also rapidly and periodically make a break in the circuit; this action being like that of a common vibrating bell only more rapid and uniform. In series with this circuit-making and breaking device was connected electrically the second part of the invention.

This consisted of an electro-magnet and a magnetic toothed wheel, so arranged that the wheel teeth could revolve near the poles of the magnet. If now the toothed wheel be revolved at such a speed that the teeth nearest to the poles of the magnet are approaching those poles at the instant the current impulse is being sent through the circuit, and are leaving while the current is broken, it is evident that the electro magnet will tend to pull the teeth nearer the poles, and thus act like a synchronous motor.

This motor armature will advance one step or tooth for each vibration of the fork, and La Cour found that after the synchronous motion was started, it would not be interrupted even if some of the current impulses from the initial station were omitted, as the momentum of the revolving toothed wheel or armature would carry it on so it would not fall out of step. This was a very fortunate circumstance, which was later made to serve a good purpose in telegraphic apparatus.

It was the task of developing this motor mechanism into a practical working multiplex telegraph apparatus that Mr. Delany and his co-worker, Mr. Edward A. Calahan of Brooklyn, undertook to accomplish.

They worked hard and long, hoping to produce a practical apparatus using but a single circuit for transmitting the currents for telegraphic signals and for motor operation and regulation, but after many failures they both decided that it was a waste of time to continue that plan and accordingly began to spend their time and energy on the development of a system using a separate wire for the regulating device.

One day as Mr. Delany sat alone watching the operation of the experimental apparatus, he took from his pocket a small rubber band and almost without forethought slipped it over the tines of the vibrating fork. Immediately the fork began vibrating more rapidly. This at once attracted his attention and he began to consider the cause of the change. He pushed the rubber band down nearer the base of the fork and the rate of vibration diminished.

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In trying to account for this action, Mr. Delany's reasoning induced him to try the effect of a magnetic field on the rate of vibration. He finally concluded that the most practical way to regulate the vibration of a fork was by means of a small electro-magnet placed between the tines—sending current through the coil increased the rate of vibration as needed.

Here was a key to the solution of the problem of motor regulation over the same wire which was used for telegraphic transmission, as pointed out later.

The apparatus used for combining and selecting the various multiplex currents consisted of a commutator, one or more segments of which was connected to each of the multiplex circuits, and a revolving brush or contact finger which was electrically connected to the transmitting line. This brush was mechanically connected to the armature of La Cour's motor and rapidly rotated thereby, thus connecting in rapid succession each of the commutator segments with the line. A similar apparatus at the other terminal of the line also made connection in the same manner to an equal number of corresponding commutator segments at the same instant. If these connections are made with sufficient rapidity, and if the brushes are moving synchronously, there is practically continuous connection between each segment in the commutator at one station and the corresponding segment at the other station. From these segments, therefore, we may connect ordinary electro magnetic telegraph instruments as we would from ordinary line terminals.

Since the motors are controlled by the current impulses made by the vibrating forks, it is evident that any means which will increase the rate of vibration of the controlling fork at one end will accelerate the motor under its control. This Mr. Delany accomplishes automatically by having certain commutator segments connected to the circuits of the correcting electro-magnets in such a way that when one contact brush gets behind the segment corresponding to that with which the other brush connects at that instant, a current will be sent through the correcting magnet and thus accelerate the tardy brush. By this system of multiplex telegraphy it is possible and practicable to send over one wire as many messages as would be sent over a dozen separate circuits by the simple method commonly used, and each circuit is just as independent of the others as though they had no parts in common.

Multiplex telegraphy is, however, not the only method by which the efficiency of a telegraph line may be increased, and

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Mr. Delany was among the first to realize that the same result would be accomplished by transmitting messages with sufficiently increased rapidity. He accordingly worked out a system which is capable of transmitting and receiving at enormously high speed. In 1883 he was granted a number of patents for automatic high speed telegraph apparatus.

Briefly, this automatic system consists of an automatic machine transmitter, operated by a perforated non conducting paper tape. By means of suitable motor driving mechanism this tape is caused to pass between two or more metallic brushes, thus making and breaking the circuit.

The receiving apparatus consists of mechanism for driving a chemically prepared conducting tape over a non-conducting roller. Above this roller and pressing lightly upon the prepared tape are three needles or contact brushes, one of iron and the other two of platinum. The iron needle is connected to the line and the platinum needles to the ground.

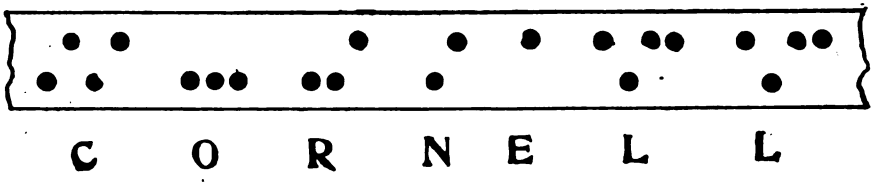

FIG. I.

The tape used to operate the transmitter had to be perforated by a special machine, the first tape being shown in Fig. 1. This perforator was operated by hand. It consists of a box containing a roll of plain paper tape about half an inch wide. This tape is fed through a slot and between two cylinders which automatically pull it forward about three-sixteenths of an inch each time one of the levers at the top is depressed. Depressing the lever at the left punches a small hole in the tape near one edge. Depressing the lever at the right side punches a similar hole near the other edge of the tape. Depressing the middle lever does not punch any hole but simply moves the tape forward one space. In operating, the levers are struck with mallets as seen in the cut, one being held in each hand. The holes punched by one lever correspond to dots while those punched by the other lever correspond to dashes. Hence, if we wish to write the letter C, which in the International Code is represented by dash, dot, dash, dot,

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we would strike the left lever, the right, the left and the right in succession. The resulting tape would be as shown at the left end of Fig. 2. The other letters on the tape finish out the word "Cornell", as indicated.

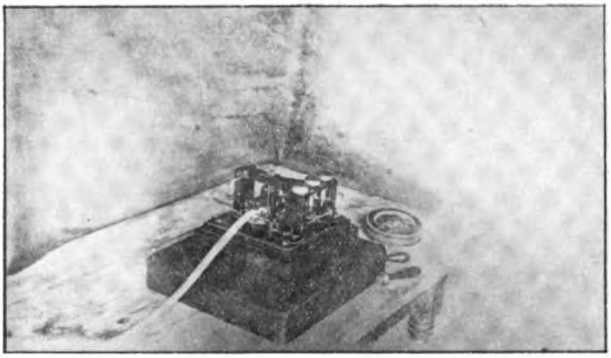

FIG. II.

The operation of the transmitter and receiver requires at each station a source of direct current, to supply both positive and negative current as in the Edison three wire system. The voltage required between neutral and outside wires depends upon the speed of transmission and conditions of the line, 110 volts being sufficient for the experimental line used. This line had a resistance of about 1200 ohms and a capacity of a little over 6 microfarads.

In the system using the above mentioned tape, positive current is sent over the line when each of the holes, in one row on the tape, passes under a contact brush; and negative when a hole in the other row passes under a corresponding brush. Hence as the tape passes through the transmitter a rapid succession of positive and negative impulses is sent over the line, and produces on the moving chemically prepared receiving tape, by electrolytic action, a permanent record, appearing as a series of lines.

The preparation of these tapes for the transmitter requires the operation of a machine with which the average telegraph operator is not only unfamiliar, but with which he will not willingly work. This was a serious objection to the use of the system, for it required a separate force of employees for perforating the tape. In order to obviate this objection Mr. Delany modified the system and built an electro-magnetic perforator which is shown

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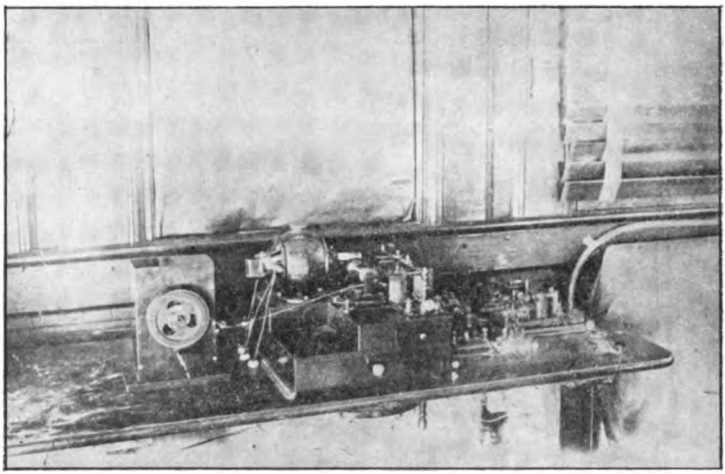

FIG. III.

in Fig. 3. This perforator can be operated by any regular operator with a Morse Key, and this key and operator may be in the same office with the perforator, or they may be at any branch office while the perforator is at the main or central office.

The operator's branch circuit is simply connected to a first relay which is connected to two other relays. These relays operate in such a way that the instant the Morse key is closed, the circuit through one of the perforating magnets is closed, and then opened again, so that the punch enters the paper and at once returns, allowing the paper tape to be drawn forward by the motor and mechanism shown in the figure. The tape then moves on uninterruptedly until the Morse key is released when the relays operate in such a way as to close and then open the circuit through the other punching magnet, which punches a hole near the other edge of the tape. It is therefore evident that with the tape thus produced, the holes near one edge of the tape indicate the instants at which the Morse key was closed, while the holes in the other row indicate the instants when the key was opened. Hence it requires two holes in the paper to indicate either a dot or a dash and they are distinguished by the linear distance between the holes. That is to say, the distance between the first hole and the second represents the time during which the circuit was closed, and of course the distance between the second and third holes will represent a "space", *i. e.* when no current is

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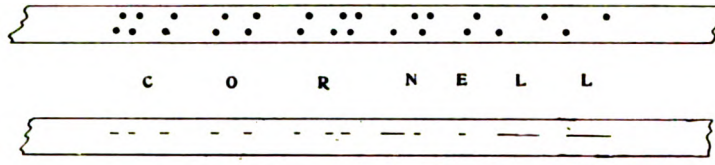

FIG. IV.

flowing. If, therefore, we wish to write the name "Cornell" on this machine and in the old Morse Code we would make a tape as shown in Fig. 4.

The small motor shown in the cut of the perforator is, like those on the receiver and transmitter, operated from the same source of current supply as that from which the transmitting current is taken, and each motor is used to draw the tape past the transmitter or contact brushes.

The instruments shown in Fig. 1 are similar to the ones used for practical work by the Penn. R. R. Co., and have transmitted from 600 to 800 words per minute over lines more than 200 miles long. In this transmitter—as shown at the left of Fig. 5—the perforated tape is drawn between two sets of contact brushes, each row of holes registering with the corresponding positive or negative set of brushes, and each hole sending a corresponding positive or negative impulse over the line. Every dot and every dash is here represented by two holes on the tape, one in each row, and the line receives first a positive charge and then a negative charge for each dot or dash. Furthermore each current impulse has a very short duration and all of them are for equal time, which is approximately the $\frac{1}{16}$th part of a second. One

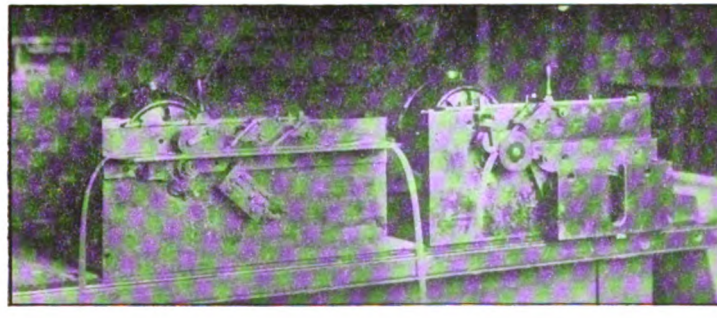

FIG. V.

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might at first thought expect to find a continuous row of equal dots on the receiving tape, for that corresponds with what is sent into the line, but this is not the case.

Heretofore the capacity of telegraph lines has caused great difficulties for rapid systems, but Mr. Delany, instead of trying to get rid of it, actually makes good use of it, and even adds extra capacity in order to obtain better results. He sends into the line at the transmitting terminal what are practically instantaneous charges of current, first positive and then negative. When the line is positively charged it discharges through the

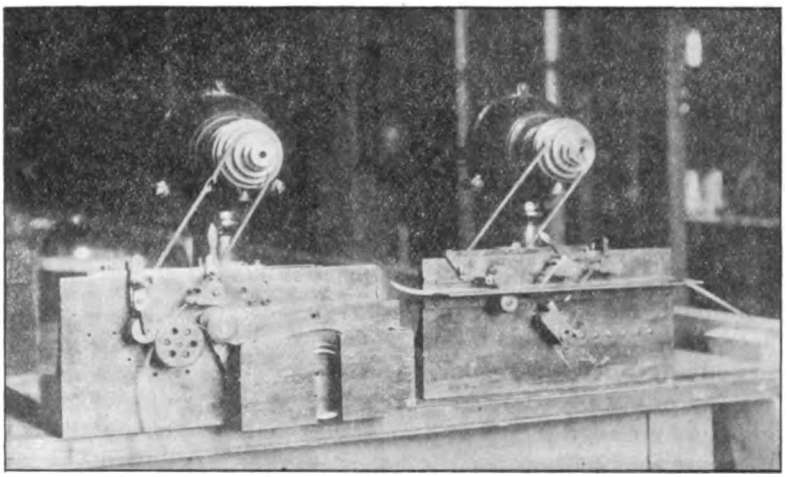

FIG. VI.

receiver, but not so rapidly as it was charged, and this "tailing", as it is called, supplies current to prolong the short dot into a dash several inches long, if it is not cut off before by means of the following charge of negative electricity, which instantly reverses the direction of current through the receiving tape.

The current from the line is led down to and into the surface of the prepared tape, through an iron wire, but leaves the surface on its way to ground via platinum contacts. When the iron wire is an anode, electrolytic action produces a decomposition which colors the tape and produces a deep blue line, but when the current is reversed and the iron is the cathode practically no decomposition of iron or platinum takes place and so the tape is left yellow. It will therefore be seen that we will have produced

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upon the receiving tape a blue line corresponding to the time when the Morse key was depressed, which gives a reproduction of the original message in the Morse code, and it may have been transmitted over a long wire at the rate of 800 words per minute.

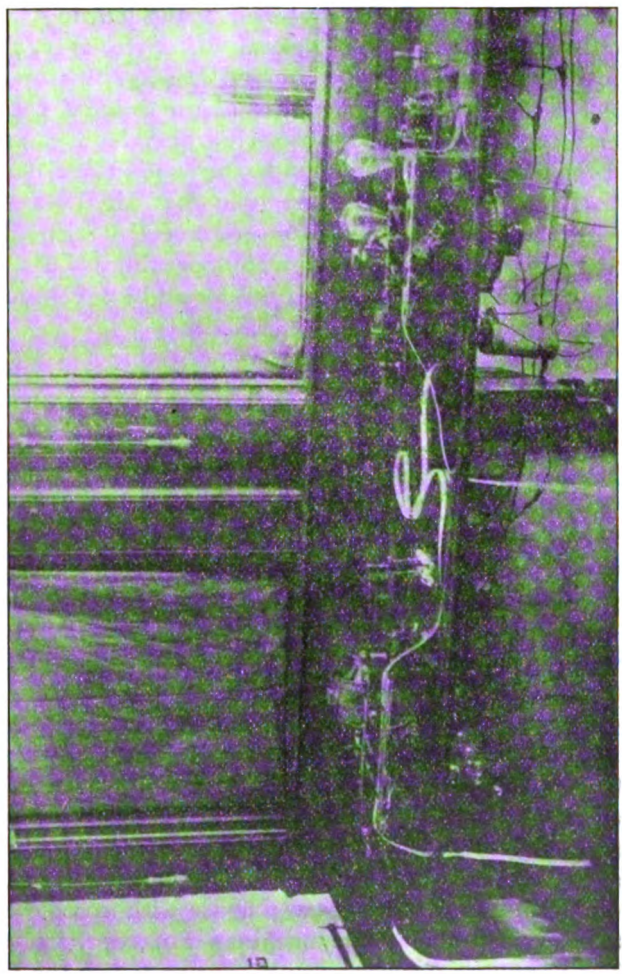

FIG. VII.

The lower line of Fig. 4 shows a careful reproduction (somewhat reduced in size) from a tape as actually received by the instrument shown in Fig. 5 at the right. It will be noticed that there is a slight tapering of the dashes showing the gradual diminution of the discharging current.

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Besides these regular machines Mr. Delany exhibited a pair of very high speed instruments which were capable of transmitting over special lines at the rate of 8,000 words per minute. These machines are shown in Fig. 6, and they are similar to others, but are provided with high speed driving pulleys on the motor. The transmitter is at the right, the receiver at the left, in this cut. Still another modification of this system was shown (Fig. 7).

It is possible for good operators to send messages by the Morse key as fast as the receiving operator can write it down, but when typewriters were introduced, the receiving operator had an easy time to keep up with the sending operator, and in fact had time to spare. It was to save this spare time that Mr. Delany proposed to use the machine transmitter in connection with a Morse receiver, or a telephone receiver, and by speeding up his motor he could give the modern receiving operator all he needed to keep him busy.

The "Steam-turbine", an engine belonging to a type of which the first recorded illustration was exhibited by Hero the Younger, about two thousand years ago, but which has only within the last fifteen or twenty years been made commercially successful, by Dow, de Laval, Parsons and Curtis, seems to be coming forward with remarkable rapidity. It is now reported that the General Electric Co., who hold the patents on the last named machine, are constructing it for the market and have about completed at least one, of 750 horse-power, which rivals the best reciprocating engines of similiar power in its efficiency and its economy of steam and fuel. The Westinghouse-Parsons turbine has been built in sizes as great as 2500 horse-power and the company is ready to contract for similar machines of any size demanded. The London Underground Railway has decided, it is stated by the London technical journals, to equip its power house with 100,000 horse-power, to be divided among ten machines of 10,000 horse-power each. The passenger steamer recently constructed on the Clyde, the "King Edward", is to be duplicated, with increased power, and it is now rumored that the Cunard Co. is seriously studying the question of adopting the two-thousand-year-old-turbine, in its modern form, for a 25-knot trans-atlantic steamer, requiring no less than 48,000 horse-power.

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MEASUREMENT OF FLOW OF WATER IN PIPES.

EDWARD S. COLE, '94.

In 1896 there was need of means for measuring the flow of water in the water-works pipe system of Terre Haute, Ind., for which John A. Cole, M. Am. Soc. C. E., was consulting engineer, and after considering the use of the Venturi, the Deacon, and the ordinary disc meters, it was decided that, for the purposes of a waste-water survey, it would be advisable to find some more economical method of measuring the flow of water in pipes.

The writer, who is associated with Mr. John A. Cole, finally acted on a suggestion obtained from Professor R. C. Carpenter's work, "Experimental Engineering," regarding the Pitot tube, as applied to water mains.

A search was made among technical papers, etc., and correspondence was carried on with hydraulic engineers, for the purpose of ascertaining what had been done by others in this field, but little help could be found, aside from descriptions of the open-stream form of instrument, by Darcy, in *Mémoires* of the Société des Ingénieurs Civils de France, and by several more recent investigators in open-stream work.

The writer, therefore, had no choice but to work out alone the many little details, which at first presented exceedingly great difficulties, especially when the object sought was accuracy at the lowest possible velocities.

Two orifice tubes were finally adopted which could be introduced through a 1-in. corporation cock by means of a special cap, each with a hook bent 90° and provided with a "cut-water." Many series of calibrations were made with orifices and tubes of various diameters, but, finally, a choice was made of an orifice having an internal diameter of $\frac{1}{8}$ in., made of common $\frac{3}{16}$-in. brass tubing, fitted to $\frac{1}{4}$-in. tubes.

It was found that an orifice and tube of this size gave more reliable indications at low velocities, and that there was less trouble with negative readings or failure to return to equilibrium at no flow.

A glass U-tube, 22 ins. long and having an internal diameter of $\frac{5}{16}$ in., was used from the first with excellent results. Connections were made with $\frac{1}{4}$-in. cloth insertion rubber tubing, and a blow-off was located at the top of each connection to remove air. It was found that small brass pinch cocks were best adapted to shutting off the water at these blow-offs, and, in fact, after re-

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peated failures, it was decided that no form of ordinary valve was at all suitable, owing to the likelihood of the occurence of minute seepage or leaks.

The lower half of the U-tube was filled with a mixture of carbon tetrachloride and gasoline, with a specific gravity of 1.25 at ordinary temperatures. Careful notes were made of the temperature at which observations were taken, and temperature corrections were applied where found necessary, although in some places the specific gravity changed to suit the temperature at which the tests were being made, so that no substantial correction was required. The object was to maintain uniformly a differential effect within the U-tube, equivalent to four times the simple waterhead. This ratio of 4 to 1 in the manometer was used in all the calibrations, and was found most convenient for the range of velocities used.

In order to obtain a rating of the Pitot tube, a series of standard cast-iron water pipes was placed in line and provided with a supply of water from a reservoir giving a constant pressure of approximately 10 pounds. The discharge was measured over carefully calibrated rectangular weirs, and means were provided for regulating the flow through the line of pipes. In this way many series of experiments were made, comparing the deflection of the U-tube at the center of the pipe with the discharge, as shown by the weir for each of the various sizes of pipe tested. Special study was made as to the ratio of mean to center velocity within the pipes calibrated, and it was found that the ratio of mean to center velocity is not constant for pipes of all sizes, though it may be for various velocities in the same pipe.

It may be of interest to add here, that considerable time was spent in perfecting a recording device for this instrument. It was found that photography was the only practicable means of registering continuously the deflections in the U-tube. Figure I shows the recording instrument, which, for the lack of a better name, has been called the photo-pitometer. This instrument combines, upon one photographic diagram, a record of the static variations within the pipe, with a record of the U-tube deflections, the latter, of necessity, being half deflections as shown on the U-tube. The instrument has shown itself capable of producing a good continuous record upon ordinary Velox paper, which is convenient for this use.

Notches, in the slit through which the light passes on its way to the paper, are so located that they produce horizontal rulings

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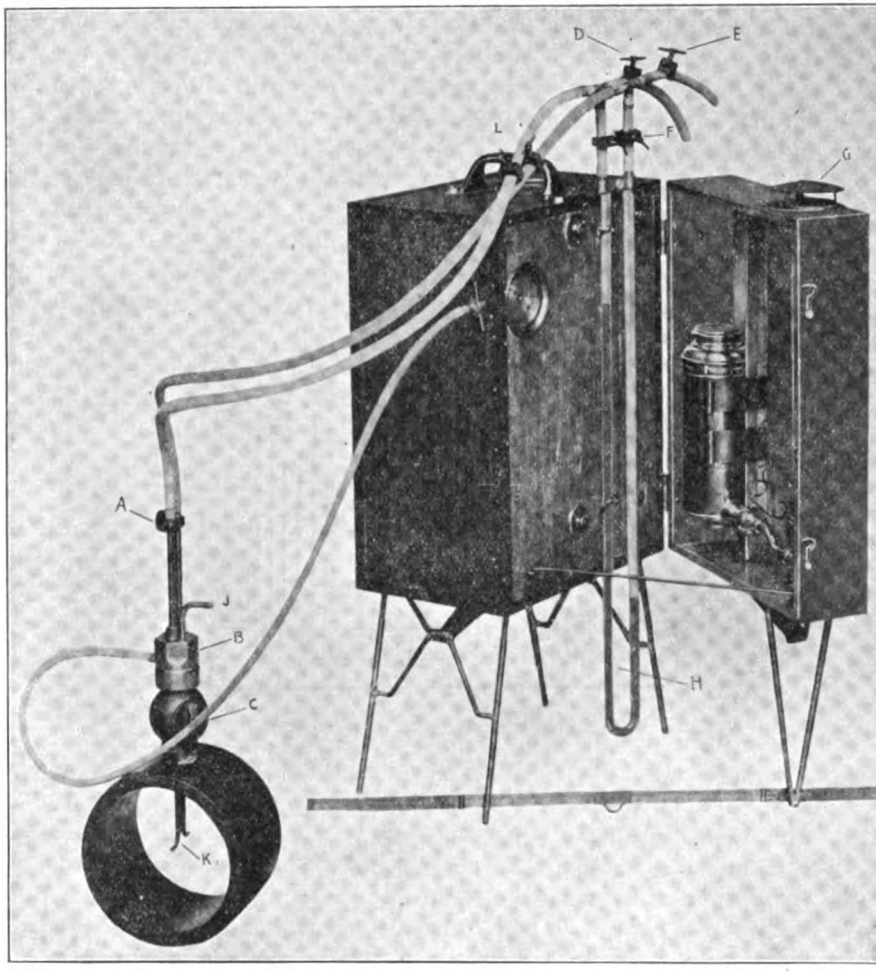

FIG. I.

upon the record, corresponding to the calibrated deflections taken from the curves. The combination of static-pressure variation with velocity is a useful feature of this instrument, as it aids in interpreting the cause of any given variation in the flow.

The pitometer, consisting of the orifice tubes *A*, *K*, the cap *B*, rubber tubing and glass tube *H*, is independent of the *Photo-Recorder* and is first put in operation as follows: Tap the main

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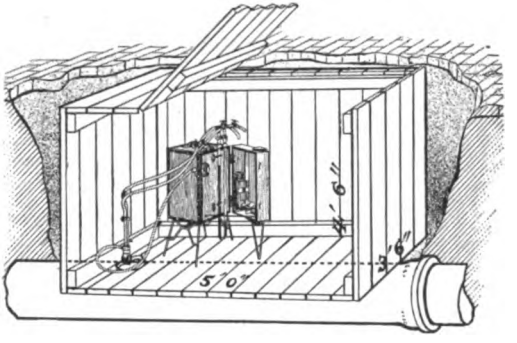
vertically with a 1-inch corporation cock, see that the orifices *K* are drawn fully up into the cap *C*, with the hooked orifices ***looking toward each other.*** At the upper end of the tubes at *A* are small lugs which serve as guides for the orifice hooks when within the pipe ; these lugs are a fixed distance above the orifices, and are exactly in line with the curved orifices or "hooks" as we shall call them. By means of these lugs and the clamp *A*, the tubes may be clamped with the orifices looking toward each other as they should when entering the corporation cock. Screw the cap *B* upon the corporation until it binds its gasket. Turn the cap so that a line passing through both tubes is exactly in line with the main.



Pitometer as set up on a street main.

In screwing up the cap *B*, care should be taken to turn the clamp *A* at the same time to avoid twisting the tubes *A K*, otherwise the delicate orifice hooks *K* will be thrown out against the rough interior of the corporation cock and their tips injured. These precautions apply specially to tubes over 15″ in length. Should injury to the orifices be suspected, the cap should be removed and the orifices repaired before proceeding further. Usually the wrench should be used only to make the last quarter turn or so to tighten the gasket and bring the tubes exactly in line with the water main.

The pinch cocks, *L*, *D*, *E*, *F*, should be closed on the rubber tubes and the latter firmly wired on. The shut-off cock *C* in the corporation is now opened wide, leaving the orifices still up in the cap. All is now ready to attach the glass U tube, which should be filled half full of the standard solution or "Liquid" of 1.25 specific gravity, the upper half being filled with clean water.

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The two orifice tubes are now slowly pushed down into the main together, being firmly clamped together at *A*. When the hooks have just entered the main as indicated by the position of the lugs *A* with reference to the top of the pipe, the tubes are unclamped and each one turned half way round, re-clamping as before, but with the lugs now looking *exactly* up and down the line of the main. Then the hooks are pushed together to the center of the main. Next the bent rod *J* is pushed down to the mark which brings the tube "spreader," attached to it, just to the lower end of the corporation cock. The purpose of the spreader is to steady the brass tubes. It need only be used in pipes larger than 16 inches. In the smaller sizes the rod *J does not turn*.

The flow may now be observed by measuring the deflection from time to time with the sliding scale inserted between the glass tubes, or if desired the flow may be *photo-recorded*. A full record of 12 hours or, if desired, a 6 or 4 hour strip may be secured by clips properly spaced.

The clock may be stopped and started by means of a small lever to be found on the front of the metal clock case within the box. This will be found convenient when wishing to take the instrument out into the field with drum and paper all ready to start.

The recorder case is provided with folding legs which raise it about 8 inches above the floor to allow the U tube to stand in the proper position. The metal lamp case swings out to its position and is held in place by a long link or hook. The oil font may be removed for filling without disturbing the lamp, and is otherwise handled as with the ordinary students' lamp.

Upon the Photo-Record a vertical base line is automatically placed evary two hours for convenience in locating upon the record any particular instant when the rate of flow is desired. Horizontal black lines are drawn on the record by properly spaced notches to represent even inches above the bottom of the slit and are corrected for the angularity of the light. Any amateur photographer will readily understand how to develop and "fix" the record. Care in the use of a proper amount of Bromide solution in the developer should be observed.

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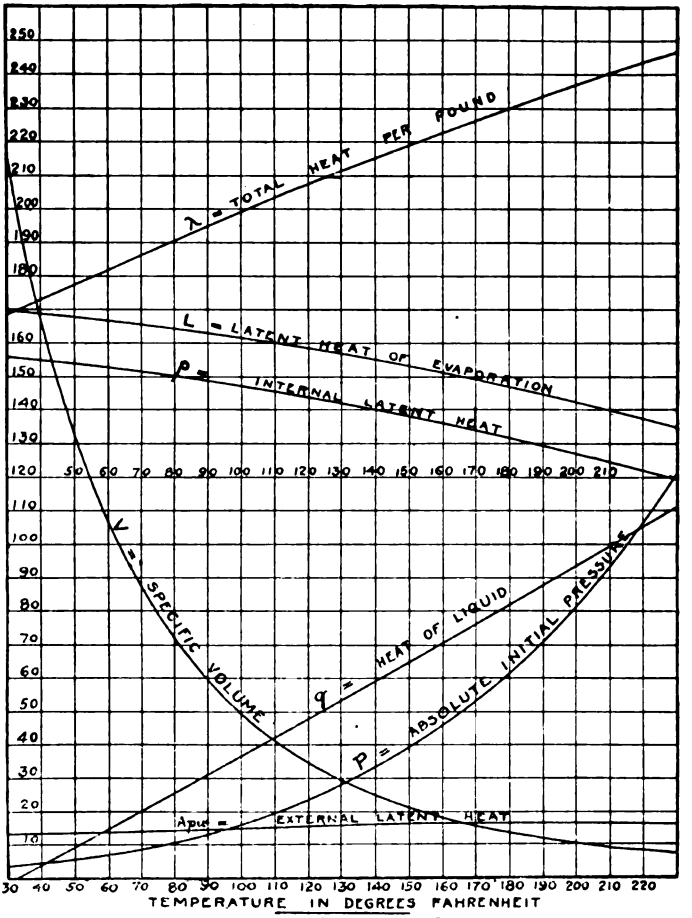
PROPERTIES OF ETHER.

A. E. FLOWERS AND A. WALTON, 1902.

In the first edition of Peabody's Tables of Steam and other Vapors is given a table of the properties of ether. It contains the values at different temperatures of the pressure at which boiling takes place, the total heat of the vapor above the freezing point



PROPERTIES OF ETHER.

of water, the internal latent heat of the vapor, external latent heat of the vapor, the heat of the liquid above the freezing point of water, the specific volume of the vapor, and the entropy of the

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liquid. These values are based on Regnault's results and were computed by means of the equations he derived, (Memoires de l'Academie Française. Vol. XXVI.) Regnault expressed all his results in units of the metric system, and the constants which he derived for these equations are applicable only for use with these units. The values in the table are therefore given in terms of the metric system.

In order to make this table convenient for use where it is desired to use British units the values have been converted into B. T. U. per pound and cubic feet per pound for the corresponding temperatures on the Fahrenheit scale. This table when computed, though accurate, is not at all in a convenient form for interpolation and in order to avoid this difficulty the values have been plotted on a large sheet of cross section paper (20" x 26") and then photographed down to a convenient size. The curves show at a glance the change of boiling pressure, volume of vapor per pound, and heat in B. T. U. per pound with change of temperature. Having given the temperature, the values of the other quantities desired may be found at once from the curves without interpolating, with quite a high degree of accuracy.

Incidentally the curves show that no errors of any magnitude were made in computing any one of the values. In one case an error in the book was checked out, and computation and comparison showed that in the value given, two of the figures had been transposed.

PROPERTIES OF THE SATURATED VAPOR OF ETHER ENGLISH UNITS.

t	p	q	λ	L	ρ	Apu	Entropy	Sp. Vol.
32	3.575	0	169.20	169.20	155.60	13.59	0	20.470
50	5.56	9.57	177.00	167.70	153.70	13.96	.01909	13.520
68	8.39	19.27	185.00	165.80	151.50	14.31	.03772	9.190
86	12.30	29.05	192.60	163.55	148.90	14.65	.05593	6.420
104	17.60	38.93	199.99	161.06	146.07	14.99	.07374	4.610
122	24.50	48.95	207.20	158.25	142.93	15.32	.09117	3.375
140	33.41	59.05	214.25	155.20	139.60	15.61	.10830	2.530
158	44.70	69.25	221.00	151.70	135.88	15.87	.12500	1.928
176	58.60	79.60	227.60	148.00	132.00	16.04	.14150	1.493
194	75.50	90.00	234.00	144.00	127.85	16.15	.15760	1.170
212	96.05	100 60	240.30	139.70	123.57	16.13	.17350	.925
230	120.60	111.20	246.20	135.02	119.03	15.98	.18910	.736
248	149.80	121.94	252.00	130.06	114.42	15.64	.20450	.583

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AN AUTHORITY ON "CHEMICAL ENGINEERING."

Mr. Wm. B. Cogswell, the Managing Director and Vice-President of the Solvay Process Co., at Syracuse and Detroit, is one of the most famous of the successful men in the chemical industries in the world. He is of English extraction, was born in Oswego, 1834, educated at the Hamilton Academy, the Root School in Syracuse, and at the Renssalaer Polytechnic Institute. He received his training and professional experience with Mr. J. C. Hoadley, the great builder of steam engines at Lawrence, Mass , where he served a regular apprenticeship as a proper supplement to his college course. He was employed by several railroads, became master mechanic of the Marietta & Cincinnati Railroad in 1856, superintendent of the Broadway Foundry at St. Louis in 1859, and in 1860 organized the works later known as those of Whitman & Barnes.

The civil war breaking out in 1861, he became a civil engineer in the U. S. Navy and served in the Dupont squadron, taking charge of the repair works at Hilton Head, S. C., and establishing a "floating workshop" in that harbor. Later he had charge of works at the Brooklyn Navy Yard for four years, returned to civil life and became engineer of construction for the Clifton Suspension Bridge at Niagara Falls, built blast furnaces at the Franklin Iron Works, in Oneida Co., N. Y., and made a success of every undertaking. He superintended the lead mines at Mine la Motte, Mo., five years, and then (1879) he began his investigation of the Solvay process for making soda ash.

He visited Europe, studied the process in its operation there, returned to the United States and studied the geology of the country and the various more or less favorable localities for such a manufacture. He finally secured a license from the inventor and organized a company of American capitalists, of whom Mr. Hazard, of Rhode Island, was the leader and finally built the present Solvay Works and worked up a business now capable of turning out 275,000 tons of soda ash, 36,000 tons of caustic soda and an equal amount of bicarbonate, annually. The total investment has become $12,000,000, although the capital is but $5,000,000. Meantime Mr. Cogswell discovered rock salt near Syracuse and thus laid the foundations of the great industry to which that city is so enormously indebted. Mr. Cogswell is a member of the American Societies of Civil, of Mining, of Mechanical Engineers, the Association for the Advancement of Science, and of other

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technical and scientific associations, of the principal clubs of his own and several other cities, and takes part in every great public movement, including that of aiding deserving young men to secure a suitable education.

Mr. Cogswell, replying to interrogatories which have been sent out regarding the prospects of young men in the chemical industries, with which he is so thoroughly familiar and with which he has had so long and so fortunate an experience, says, in effect, that his conclusions are:

(1) That he should rate the Chemical Engineers as a class of Mechanical Engineers, finding special opportunities in the great chemical industries. There should be, similarly, Industrial Chemists.

(2) That there is a growing demand for this class of engineers, and a growing opportunity for the man fitted to succeed in this department of his professional work, and for the Industrial Chemist.

(3) That these two classes should be allied in their work, the one supplementing the other.

(4) Regarding the prospects for such men, he says: "*There is no limit below the top.*"

(5) That the well-prepared Chemical Engineer, fitted by education and professional training to design, construct and operate machinery and works, with a good supplementary knowledge of the chemistry of the business with which he connects himself, may expect, with time and experience, to find opportunity to go to the top.

Mr. Cogswell expressed the same general views regarding other departments of chemical engineering, as those of iron and steel manufacture and the mechanical engineering of mines.

At a recent meeting of the Society for the Promotion of Engineering Education, Professor Turner, of Purdue University, read a paper on "Machine Work in an Engineering College," in which he makes a plea for more advanced shop work than that found possible when the students have to be instructed in the very first principles of the subject. He says: "If he has not been taught these principles before entering college, then he must learn them when he begins his work, but it would be far better if the college shop were not obliged to begin its work at the very bottom of the course. The time ought not to be far distant when the college shop may drop the work of the manual training school and take up this more advanced work, which is more in keeping

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with the other courses of the college. When this is done, the elementary work of the high or manual training schools will be one of the requirements for entrance to an engineering college. With such preparation, the student will be enabled to begin his shop work higher in the course, and thus reach a higher point than he would otherwise. He would then have a better understanding and a firmer grasp of those principles of the work which will be most beneficial to him when he enters his chosen profession."

PRICES AND WAGES.

The Baldwin Locomotive Works issued an interesting comparison in connection with its recent celebration. This relates to the *averages* of various features connected with their establishment and its product, in 1901, as compared with 1870.

	1870	1901
Locomotives built during the year	280	1,375
Number of men employed	1,822	9,281
Number of men per locomotive built	6.51	6.75
Pay per man per week	$11.66	$13.00
Tractive power per locomotive, pounds	10,461	26,965
Horse power per locomotive, at 10 miles	279	719
Horse power constructed by one man in a year	42.85	106.51

To the vastly extended use of machine tools and the standardization of parts are due the increase of 150 per cent. in the locomotive horse-power constructed by one man in a year. The largely (158 %) increased size of locomotives, as indicated by their average horse-power, accounts for the necessity of employing more men per locomotive than formerly, but the causes previously mentioned operate to keep the number down very close to what it was a third of a century ago. The tractive power has increased in the same ratio as the horse-power. Being practically a direct function of the weight on driving wheels, the tractive power increase approximates the increase in the weight on the drivers. It does not follow from this that the total weight of the engine has increased in the same ratio; but as the tractive ratio has not changed very much during the interval, such a deduction would be not far from correct.

The increase in the weekly wages per man forms an interesting basis for discussion. It is seen to amount to 11.5 %. A table has been compiled from data found in "Statistical Abstract of the United States," showing the relative prices of standard articles

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of consumption in 1901 as compared with 1870, or, when the latter figure is not to be found in the "Abstract," a somewhat later date is shown, as indicated :

TABLE.

Article	Quantity	Year	Price	1901	Decrease %
			cents		
Cotton Sheetings	yard	1870	14.58	5.54	62
" Prints	"	"	12.41	4.62	63
Fine Fleece Wool		"	48.	27.	44
			dollars		
Foundry Pig Iron	ton	"	33.25	15.87	52
Refined Bar Iron	"	"	78.96	41.22	48
Steel Rails	"	"	106.75	27.33	74.5
Cut Nails	keg, 100 lbs.	"	4.40	2.29	48
Anthracite Coal	ton	"	4.39	*3.47	18.7
Bituminous Coal	"	"	4.72	2.50	47
Wheat	bushel	1876	1.24	.73	41
Corn	"	"	67.	.46	31.5
Wheat Flour	barrel	"	6.22	3.72	40
			cents		
Eggs	dozen	"	28.	18.3	34.5
Illuminating Oil	gallon	"	14.	6 6	53
Butter	pound	"	23 9	17.3	27.5
Rice	"	1879	2.9	2.1	27.5
Tea	"	"	24.2	12.3	49
Rio Coffee	"	"	14.86	8.60	42
Granulated Sugar	"	1880	9.80	5.05	48.5
Lard	"	1882	11.78	8.87	25
			dollars		
Beef	barrel	"	13.45	9.32	31
Pork	"	"	19.79	15.62	21.5

*1900

This shows clearly that the cost of living has largely decreased during the interval under consideration, and as wages according to the Baldwin statement have substantially increased, the general comfort of the individual workman has obviously been much enhanced.

Sixty-two students of Purdue University, under the direction of Professor W. E. Goldsborough, are engaged in making an extensive test of the entire plant of the Union Traction Company of Indiana, with its 170 miles of electric railways operated from one power-house. One of the main objects of the test is to determine to what an extent a saving is effected by this extreme centralization of plant. If the results seem to warrant it, the company will extend its operations over another large section of the state of Indiana, enlarging the present power-plant for the purpose.

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THE SIBLEY JOURNAL OF ENGINEERING,
ITHACA, N. Y.

OUR frontispiece this month is from a photograph taken by Professor Moler of the Physics Department, on the afternoon of May 2. It represents Lord Kelvin, between President Schurman and Professor Nichols, standing just outside the Dynamo Laboratory.

THE meeting to welcome Lord Kelvin to the University took place in the Armory on the afternoon of May 2d, 1902. The spacious hall was completely filled, many of the audience being obliged to stand during the brief ceremony. Upon the platform were the distinguished guest of the occasion, the President of the University, the deans of the several colleges, and a number of other gentlemen more or less intimately connected with the University.

President Schurman, in the name of the trustees, deans, faculty and students, extended to Lord Kelvin a most cordial welcome.

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He said, in part: "There is a close resemblance between the spirit and the work of Lord Kelvin and the spirit and the work of Cornell University. As with our distinguished visitor, so has the dominant note of Cornell been scientific research and study, though our endeavor has been to avoid all narrowness, and to approximate to the conditions laid down by our illustrious founder:—'I would found an institution where any person can find instruction in any subject.' At the time the University was inaugurated, scientific teaching was in a state of neglect; and it was to remedy this deficiency that Ezra Cornell founded the University that bears his name The aim of our noted visitor's life has been that of the University—the advancement of mankind. This fact lends additional warmth to his welcome.

"In 1882, just twenty years ago, the University had 368 students, all told. To day, we have exactly 368 post-graduate students. We have now almost precisely as many members of the faculty and instructing staff as we then had students, while our student body as a whole has passed beyond 3,000.

"In conclusion, I am gratified to be able to announce that the receipt of the sum of $250,000 for a new physics building, upon which was conditioned Mr. Rockefeller's generous gift of a like amount, is now assured."

Professor Nichols, who followed President Schurman, spoke first of a visit which he made, twenty-five years ago, to Lord Kelvin, in Glasgow. He mentioned the fact that our guest, then known as Sir William Thomson, had already been professor of physics in Glasgow University for thirty years, and was then a distinct leader in mathematical and physical thought. His writings, even prior to that date, in either of those branches, would have entitled him to permanent recognition in the scientific world. The speaker discussed at some length Lord Kelvin's work in connection with the Atlantic cable. "Of that party of scientific explorers, Lord Kelvin was the Columbus; of that faculty of electrical engineering which gathered on the decks of the *Great Eastern*, Lord Kelvin was the dean."

Dr. Thurston, who spoke next, referred to the work of the great minds of the last century, who, beginning with Watt, gave us the steam engine and means for utilizing electrical energy. Of the multitudinous details of development and improvement, by means of which these great instruments were brought up to their present state of perfection, no one contributed a larger share than Lord Kelvin. "In the year 1824 two remarkable things

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happened: M. Sadi Carnot promulgated his great thermodynamic theory, and in the same year Lord Kelvin was born. It is an interesting coincidence that this younger man was destined to reconstruct the theory which was first given to the world in the year of his birth." Dr. Thurston then mentioned the fact that the subject of telegraphy which, particularly in its submarine form, had engrossed so much of Lord Kelvin's time and energy, was one with which both Ezra Cornell and Hiram Sibley had been closely connected, and in which each had signally distinguished himself.

Upon being presented by President Schurman, Lord Kelvin replied to the addresses which had preceded his. He spoke with great feeling of the pleasure it had given him to be able to be present and be so warmly welcomed to the University, and insisted that it was he and not the University upon whom the favor had been conferred. He said: "I have been a professor at Glasgow for fifty-three years. I will therefore be pardoned for entertaining a feeling of sentiment for that university. I have heard with great interest of the growth of Cornell University. The predominant feeling which came to my mind was one of envy—I will not attempt to conceal it—envy of the great advantages which you young men of Cornell University enjoy. I have been amazed at the completeness of the equipment of your shops and laboratories. You don't need to look forward to that $250,000 building. What you already have is enough to arouse my keenest envy.

"The objects of a university education are two-fold: to teach the students to earn a livelihood, and to make life worth living. All must learn in some way to make a livelihood, even those born to wealth. But the university does more than this: it embellishes and enriches life."

One of the alumni of Sibley College who had taken a master's degree in engineering and had held a scholarship meantime, feeling that he owed a large debt to the institution, wrote the Director of Sibley College, during the past college-year, inquiring whether he would be permitted to place in the University Treasury, at some early date, should he find himself in a position to do so, a fund which should be accepted as representing some small part of that obligation, the proceeds to be employed in the provision of scholarships or fellowships for other young men, without means, but with ambition and talent, who might desire to take

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the same course as that which had done so much for him. These funds will presumably come to us after a time; but it is also extremely probable that only the suggestion is required by many alumni to bring back from each some part of that least of their debt—the pecuniary expense of the University in their education.

ABOUT the time this issue goes to press, elections in the Sophomore and Junior classes, and the decision upon the results of a competition in the former, will operate to name three men for the 1902-3 board of the SIBLEY JOURNAL. From our knowledge of the men who are "out" for these positions, we feel sure that the work will be left in good hands, and that it will be carried forward with the best of success.

Department Notes.

Herman Diederichs, '97, Σ Ξ, has just been appointed Assistant Professor of Experimental Engineering, the department in which he has long been an instructor.

The contract for the publication of the joint Proceedings of the Electrical Society of Cornell University and the Cornell Society of Mechanical Engineers has been awarded to Andrus & Church, the publishers of the SIBLEY JOURNAL. The volume will appear about the first of June.

Charles C. West, M.E., '00, now in the employ of the Chicago works of the American Shipbuilding Company, commonly known as the "Trust," gave a very interesting and instructive lecture before the Seniors in Naval Architecture, on Saturday morning, April 12th, and repeated the lecture before the Cornell Society of Mechanical Engineers, on the evening of April 15th. His subject was "Shipbuilding on the Great Lakes," and the lecture was illustrated by a large number of slides, by means of which he traced the construction of the typical lake freighter from the laying of the keel-blocks to the time when, with paint still wet, she steamed away from the builder's yard to take on her first cargo. The great divergence in construction practice between the ocean builders and those on the lakes, governed as the latter are by a peculiar set of conditions, was clearly demonstrated.

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Personals.

'91. Louis W. Emerick, M.E., is vice-president and general manager of the Fulton Light, Heat and Power Company, of Fulton, New York. A local paper, commenting on his selection for this important position, says: "Mr. Emerick is an electrical engineer of marked ability, having been the chief electrical engineer of the Solvay Process Company for about seven years, and chief engineer of the National Cash Register Company of Dayton, O., during the past year and a half. The extensive new additions to the plant will be made under his direction."

'91. Charles Locke Etheridge, E.E., has severed his connection with Evans, Almirall and Company, heating and ventilating engineers of New York and Chicago, to assume charge of the electrical department of the Pullman Car Works, at Pullman, Ills.

'93. William H. Boehm, M.M.E., is the Superintendent of the Fly Wheel Department of the Fidelity and Casualty Company of New York. He writes Dr. Thurston in part as follows:—"During the past year the percentage of engine pulleys and fly wheels that exploded exceeded the percentage of boiler explosions. Sound wheels operated at slow speed and apparently safe are continually going to pieces, entailing frightful loss of life and property. Fly Wheel Insurance offers protection against loss occasioned by such accidents and provides for the inspection of the engine and wheel; thus lessening the chances of accident. Like Boiler Insurance, it is valued for the inspections and because it is good business policy to carry protection against such hazards. As engine accidents are always costly the advantages of expert engine inspection are apparent.

'93. Charles J. Barr, M.E., has resigned his position as master mechanic of the South Chicago works of the Illinois Steel Company, to accept a similar post with the Dominion Iron and Steel Company, Limited, of Sydney, Nova Scotia.

'93. Thomas Hall, M.E., (M.M.E. '94), one of the "principals" connected with the Sibley "Hall and Treat" quadruple expansion engine, has organized the Mansfield, (Ohio), Engineering Company, for the purpose of building self-oiling engines of his own design. The company is putting up a new factory and erecting shop, 195′ × 75′, which, with its 20-ton electric crane, will be ready for use about July 1st. At that time the present force of 90 men will be increased to 150.

'94. Joseph Sterling Goddard, M.E., is chief draughtsman for the Chicago, Burlington and Quincy Railroad Company.

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'94. Daniel A. Mason, E.E., has established himself as a consulting Mechanical and Electrical Engineer, being senior member of the firm of Mason and Sloan, of 220 Broadway, New York City.

'00. Frederick B. Hufnagle, M.E., is superintendent of a department in the works of Jones and Laughlin, Pittsburg. He has charge of two modern mills, and has under him ten foremen and 300 workmen.

'00. Alfred Englert, M.E., has a position as draughtsman with the Manhattan Railway Company of New York City. His address is 872 DeKalb Avenue, Brooklyn.

'00. Frederick George Grimshaw, M.E., is special apprentice at the Altoona shops of the Pennsylvania Railroad Company.

'00. Carl Ernest Hardy, E.E., has been, since August, 1900, first assistant master electrician at the United States Navy Yard, Norfolk, Virginia.

'01. Irving G. Downs, M.E., is now in the office of Cornelius Vanderbilt, 100 Broadway, New York. L. A. Shepard, A.B., '92, who worked for about two years in Sibley College after graduation in Arts, is in charge of drafting in this office.

'01. George W. Ristine Jr., M.E., has an illustrated article in the recent special "Maintenance of Way" edition of the *Railway and Engineering Review.*

Ex-'84. Orville H. Ensign, M.E., is the subject of a biographical sketch in the *Electrical World and Engineer.* He has been successively in the employment of the Schenectady Locomotive Works, the United Edison Company, the Edison General Electric Company, the Redlands Electric Light and Power Company, the Los Angeles Railway Company, and now the Edison Electric Company, of California. He had charge of the first polyphase transmission in this country; and later, when the Southern California Power Company installed the 33,000-volt, 83-mile transmission from the Santa Ana River to the city of Los Angeles, he was the engineer who carried through to succes this remarkable undertaking. He is now mechanical and electrical engineer and superintendent for the Edison Electric Company, which includes the former Southern California Power Company, the Redlands Electric Light and Power Company, and the Edison Electric Company of Los Angeles, and as such, has general direction over the entire system, embracing a stretch of almost 3000 square miles of territory.

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BOOK REVIEWS.

Arithmetic of Electrical Measurements. By W. R. P. Hobbs, R.N., Associate of the Institute of Electrical Engineers ; Head-master of the Naval Torpedo School, Portsmouth. Revised to date by Dr. Richard Wormell, M.A., editor and joint author of "Electricity in the Service of Man." Ninth edition, with numerous examples, fully worked. London : Thomas Murby ; and New York : D. Van Nostrand Company ; 1902. Pp. 112. Price 50 cents.

The general scope of this little volume is clearly indicated in its title. It is, necessarily, very elementary, but none the less thorough ; well-adapted to the needs of a beginner in this field, and of the practical electrican whose theoretical training has not been extensive. A resumé of the chapters will show the ground covered :—I, Joint Resistances ; II, Division of Current in Branch Circuits ; III, IV, V, VI, Strength of Current—III, Cells in Series ; IV, Cells in Parallel ; V, Cells in Series and Parallel ; VI, Cells in Opposition VII, Electro-Motive Force ; VIII, Resistance ; IX, Battery Power ; X, Best Arrangement of Cells ; XI, Resistance of Conductors ; XII, Electric Lighting ; XIII, Miscellaneous Exercises. Occasional explanatory figures aid in following the text.

Armature Windings of Direct Current Dynamos : Extension and Application of a General Winding Rule. By E. Arnold, Engineer, Assistant Professor in Electrotechines and Machine Design at the Riga Polytechnic School. Translated from the original German by Francis B. DeGress, M.E., chief of the testing department, Crocker-Wheeler Company, New York : D. Van Nostrand Company, 1902. Pp. 124 + xii. 146 Illustrations. Price, $2.00.

Beginning with the first principles connecting the flow of current in a conductor with its motion in a magnetic field, the simplest forms of connections are traced to more and more complex ones, until finally the entire subject of both closed and open-coil windings is covered, with the ring, drum and disc forms of each. Written primarily for presenting to the students under the author's instruction, in a brief and simple manner, the various methods of winding armatures for commercial use, the work has a much wider field of usefulness, being well adapted for consultation in designing any form of direct current machine. Especial attention has been paid to the windings of multi-polar machines, which, (so says the preface) have been more or less neglected by previous works on electrotechnics. The general concord of text and illustrations is splendid. The typography is notably good.

Standard Polyphase Apparatus and Systems. By Maurice A. Oudin, M.S., M.A.I.E.E. Third edition, revised. New York : D. Van Nostrand Company ; and London : Sampson Low, Marston & Company ; 1902. Pp. 289 + vii. 169 illustrations. Price, $3.00

This work begins with the most elementary phases of its subject, and carries the reader, by more or less rapid steps, into current practice. The ground is thoroughly covered, as the following list of chapter titles will testify :—Definitions, Generators, Induction Motors, Synchronous Motors, Rotary Converters, Static Transformers, Station Equipment and General Apparatus, Two Phase System, Three-Phase System, Monocyclic System, Choice of Frequency, Relative Weights of Copper for Various Systems, Calculation of Transmission Lines, and (*Appendix*) Standardization of Generators, Motors and Transformers. Next to the broad subject of Generators, which occupies two chapters, the Induction Motor is accorded the most extensive treatment. Under the head of Station Equipment such items as switches, cut-outs, insulators and circuit breakers are discussed. Throughout the work the illustrations are scattered profusely, in half tones and line cuts, offering a splendid aid to the text in its explanatory function. Typography and illustrations are excellent.

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CLASS OF 1902.

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THE SIBLEY JOURNAL OF ENGINEERING.

VOL. XVI. JUNE, 1902. No. 9.

IN CORNELL UNIVERSITY.

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislature of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

AERIAL NAVIGATION: THE PROGRESSIVE DEVELOPMENT OF AIR-SHIPS.*

CARL E. MYERS.

The fatal accident in Paris, France, last Monday, May 13, 1902, when the gasoline motor air ship of Augusto Severo, a rival of Santos Dumont, caught fire or exploded in mid air, is a revelation of danger to careless pioneers. It is not so remarkable as the fact that 117 years have elapsed since the sole other accident occurred to Philatre de Roziers, in the same city, during a pioneer ascent with a combined fire and hydrogen balloon. Both of these accidents were the result of incaution and inexperience.

That careful aerial navigation is not essentially dangerous is proven by the fact that I am before you to-day, alive and unharmed, at the age of sixty, after a quarter century spent in aerial travels, ranging over thousands of miles, embracing twenty-one of these United States, the District of Columbia, and the Canadas.

During all this time the only real danger that I seem to have run was from a single possible collision between my air-ship and a railroad locomotive! I had made a flight with my skycyle from Pittsburg, Pa., in the presence of three hundred thousand

* Lecture delivered before Sibley College, May 16th, 1902.

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spectators, gathered at one Fourth of July Celebration, when the temperature was 105°, in the shade, on the ground. It was a great relief to get up into the cooler air. The scene below me was the most wonderful of my experience. Three great rivers joined together and divided a labyrinth of winding roads, encircling the hills, as do those here climbing to your Campus, making the whole visible territory an enchanting landscape garden, flat as any map.

Imagine yourselves in a captive balloon, poised above Cornell, the city of Ithaca, and with Cayuga Lake stretching upward toward the horizon!

After I had strolled about in the air half an hour, tracing the twisting paths below me, I sought a safe place for a landing, clear away from the mob which would have destroyed me in their excitement had I landed in their midst.

The only space clear from trees and people in my vicinity was the railroad track. I hovered over it while two long trains met and passed, and then I dropped, just behind, on the cleared rails, when along came a wildcat locomotive with a terrible racket of bell and whistle, and I almost lost my life, through fright, before I could hustle my half-emptied sky cycle gas spindle off the track. What would have happened to that locomotive had my hydrogen exploded, I can't think.

It was the only time in my high career that I have been "real scared" myself; but at another time I nearly frightened to death a young Cannuck farm hand, near Lewiston, Maine, one November day, when I landed in freezing weather and a thirty mile wind, and the only person in sight ran away screaming when I called for help to check my skycycle. He flew into the farm house crying, "Oh Lord, come quick, come quick; the devil is after me big as a house, and talks just like a man"! You will appreciate his horror when I show you some of the dreadful airships I shall now project on the screen.

In tracing the progress of ballooning toward aerial navigation I will briefly review its early history. In 1783 two sons of Pierre Montgolfier, a rich paper maker of Annonay, France, were in the prime of life and engaged in physical science.

Convinced by minor experiments that a heat of 180° rarified the air and made it occupy about double its former space, or that this degree diminished its weight by one half, Joseph speculated on what might be the best shape and material of a vessel which being filled with air thus heated would raise itself from the earth.

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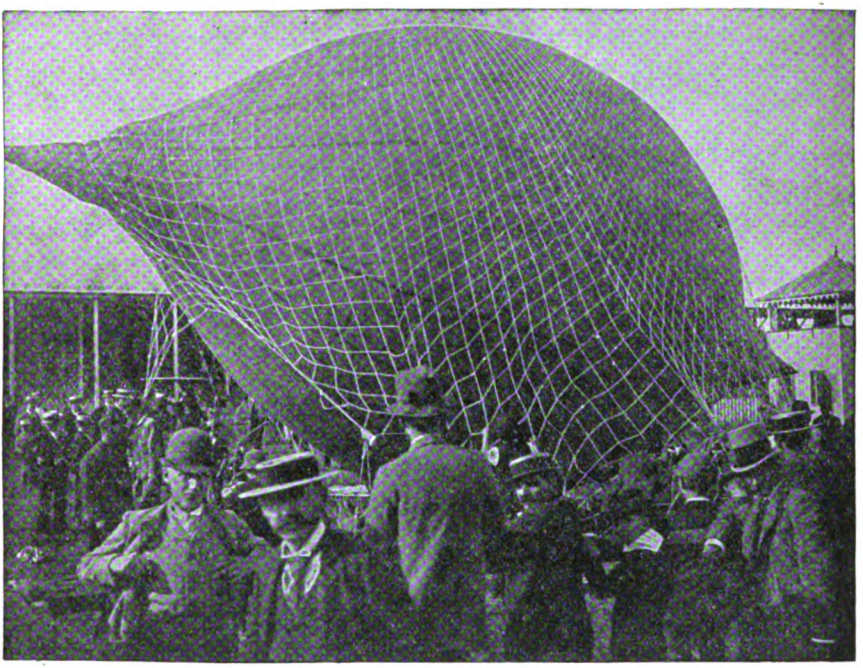

FIG. I.

His first balloon, of thin silk, containing about 78 cubic inches of heated air, arose to the roof of his apartment, in November, 1782, at Avignon, where he then was.

At Annonay, later, Joseph and his brother performed the same experiment in open air. This machine, of about 66 cubic feet capacity, filled with heated air tore away from its fastenings and arose about 300 feet. Then they made a very large and strong balloon to bring their discovery before the public, on June 5th, 1783, the nobility being present.

The balloon was first filled with smoke, then thought necessary. It was a paper sack, spherical, 35 feet high, made of sections buttoned together like clothing, and leaked badly through seams. It arose to over a mile in 10 minutes, and fell gently 7,200 feet distant.

This successful pioneer feat secured forever to the Montgolfer brothers the glory of one of the most astounding discoveries. Enthusiasm indescribable spread in all directions. Hydrogen had

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been just discovered, 6 years previous, by Cavendish. It now became famous. Prof. Charles, of Paris, assisted by two practical men, the brothers Roberts, at once built a balloon of taffeta, 12 feet diameter, covered with rubber. This ascended from the Champ de Mars, August 27, 1783, through the clouds, burst above them from over expansion, and terrified the peasants as a monster from the skies when it fell, and was assailed with stones, flails and pitchforks.

At the fête of Versailles, Sept. 19, 1783, 300,000 spectators, including the noblest, most illustrious and learned men of France witnessed, with the royal family, the Montgolfier's next success, the vessel carrying a cage containing a sheep and some pigeons as the first living passengers.

With a Montgolfier balloon of 47 feet diameter and 60,000 cubic feet capacity, on Oct. 15th, Philatre de Roziers ascended 80 feet, while the balloon was held by a rope. This was the first captive balloon observation in the world. Two days later this experiment was repeated, amid unbounded excitement. "All the world came to see."

The one aim of these experiments was aerial navigation. On the 21st of October, 1783, Roziers and the Marquis d'Arlandes ascended free. Their flight was nearly five miles in about twenty minutes, to over half a mile in height. It was a feat of thrilling hardihood almost unique, the vessel being sustained by the fire carried and fed by straw faggots thrown into a pot hung on chains below.

Prof. Charles and the brothers Roberts began construction of a hydrogen gas balloon, with car to carry one or two passengers, creating at one bound the art of aerostation as practiced to this day; for he invented the valve for escape of gas, the ballast for adjusting balance and elevation, the car for travelers, the rubber coating for retaining the hydrogen, the netting for harnessing the balloon and the use of the barometer to indicate the altitude.

Six hundred thousand people, three-fourths of the entire population of Paris, witnessed the ascension, Dec. 1st, 1783, of Charles and Roberts, who landed after a two hours voyage, twenty-seven miles from Paris. Here Roberts alighted and Charles re-ascended to a great height, and suffered so much from cold and his too rapid rise that he vowed never to repeat it. Montgolfier never made an ascension, and Charles only this one, but they opened the paths of the air, which at least a million human beings have since pursued.

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In the endeavor to control the altitude or vertical movement at will, without casting out ballast or gear, Philater des Roziers, the pioneer aeronaut, made the first marked departure from the usual construction, and with it met a tragic death, June 15th, 1785. He surmounted a tubular fire balloon with a sphere of hydrogen gas, as shown here upon the screen. The gas balloon expanded in the lighter air above, and burst, as did the motor air-ship of Sevaro, first referred to, from a like cause—over-expansion without suitable relief, in 1902. Severo's gas took fire and burned, Rozier's did not, as his furnace fell unlighted.

July 15th, 1784, marks the first radical change from the form of the spherical gas balloon. This elliptical-shaped vessel, a prolate spheroid, or "eggoon", was built for the Duke of Chartres

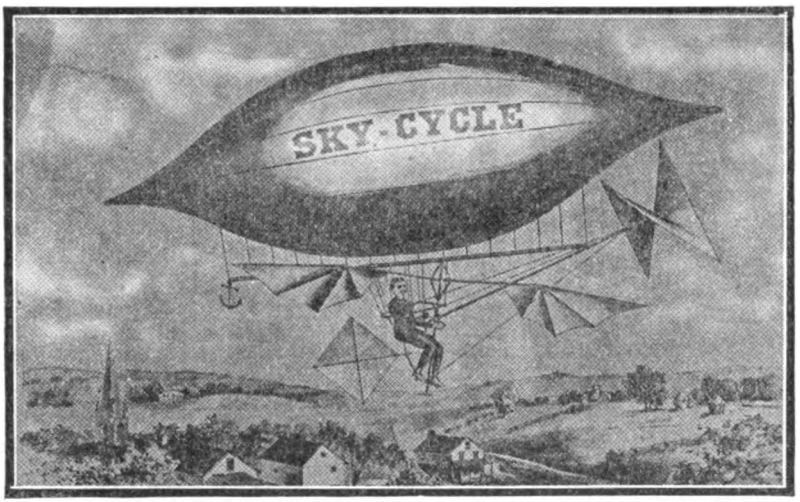

FIG II.

on a plan supplied by Meuner, and had within it the first "balloonet," or small balloon filled with air to act as an adjustor of pressure and permit changes of elevation without change of form in the larger vessel. Captive balloons and air-ships use this old device for similar purposes in some European construction.

Among middle day air-ships we find the scheme of Prof. Cardenon, of Italy. This is an ellipse, with cone bow and stern. Its chief merit is simplicity. Its chief defect is the screw on its pointed bow, which ejects its waste air against its own body, and retards its advance. Had its screw been lower it would have aided the support, as I will later show you in my earliest gear kite.

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In 1850 we have, among others Petier's system of connected balloons in train, each with its propeller,—an impracticable monster. This forestalls Count Zeppelin's famous failure of 1900.

The air-ship of Henri Gifford, 1852, was a wonderfully daring conception, a hydrogen gas spindle propelled by a steam-engine. Two voyages were made, and its inventor, the creator of the steam injector and the great Paris captive balloon, left his air-ship, (the first motor, screw-propelled air-craft), for others to develop. It was 144 feet long, 39 feet diameter, of 88,000 cubic feet capacity, and ran seven miles per hour. It chiefly lacked the light weight powerful motors now available.

Marriot's steam "Aviator" seems an advance as a beautiful spindle-shaped construction of rattan, covered with balloon cloth, elevated by aeroplanes and buoyed by hydrogen. It was propelled by a steam-engine, and a chamber containing live steam under pressure, without fire. It made a few short trips in California, out of doors, and held by a string.

The electric balloon of Renord and Krebs, 1884, thus far proved the most successful of power-propelled air-ships. It made 7 out door voyages from the French Military Balloon School at Mendon, during 5 of which it returned to its place of departure, and has attained a maximum speed of 13 miles per hour. With modern light weight explosion motors this same ship could attain twice or thrice this speed. It was 165 feet long, 27 feet diameter, and of 66,000 cubic feet respectively.

The electric balloon of Gaston Tissandier antedates that of Renand and Krebs, but it had less power, less capacity for gas, and its shape was not so favorable, or elongated. It was 91 feet long, 30 feet diameter, with cubical capacity 37,000 feet. It ran nearly 7 miles per hour, with two passengers, and made two ascents.

The car of Tissandier's balloon shows his screw propeller and electric engine driven by bichromate of potash batteries, controlled by gravity system. It was the first successful electric air craft. Either of these two electrically propelled air-ships, if provided with the latest explosion motors supplied to Santos-Dumont, could have distanced his and all subsequent air-ships out of sight.

The Dupuy de Lôme air-ship was the first to make wholesale use of muscular power for propulsion. The French government furnished funds for its construction in 1872. Fourteen men were carried by it, eight working the screw at one time. It was 118 feet long, 48 feet diameter. It made one flight, at 6 miles per hour.

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The air-ship of M. Yon proposed to work by steam or explosive force. The propellers just below the gas spindle, on each side, may serve to both steer and propel. Like the gas spindles previously shown, its outline consists of simple curves, joining at each extremity.

The aerial ship of Dr. Woelfert, of Berlin, is a cylinder, terminating with a hemisphere at each end. It made three ascents, June, 1883, but did not succeed in stemming the wind, nor did it make any headway.

Richell's flying machine, 1878, was of still worse shape, consisting of a cylinder about 26 feet long, 13 feet diameter, with flat ends, dangerously secured in worsted bands instead of netting, and without escape valve. Its operator weighed 90 lbs. It had an ingenious arrangement for propelling and guiding, by a four bladed fan arranged to face in any desired direction. The operator worked the screw shaft by hand cranks. The machinery weighed 48 pounds, without the bag, whose shape was such that it was impossible to navigate the air in any sense. It made an open air ascent at Hartford, Conn., and again near Boston. It was the first vessel in America which attempted to give out-door, public exhibitions.

Carl Peterson's aerial train is known to some Brooklyn people who invested stock in it some years ago. It was formed in cylindrical sections, each with its own propeller and passengers, the bow and stern being pointed. It got no further than the pockets of its stockholders. The system of construction is an advance on Petier's train of spherical balloons, and differs chiefly from Zeppelin's in being composed of separate, detachable sections, each with its own motor.

The Campbell air-ship of Brooklyn was planned as shown, with an oval-shaped gas bag, but the two man spindle and four smaller working models built for him by me had sharp-pointed bow and stern. The smallest of these, 7 feet long, 28 inches diameter, was a beautiful air-craft. Exhibited indoors first at Coney Island, N. Y., it escaped from an open transom, with a load of silver dollars used to ballast it, the entire audience chasing it and scrambling for the dollars scattered by vain attempts to stop it.

This farce was followed by a tragedy. I had provided the large two-man vessel with the usual gas escape valve. The inventor removed this valve as an insult to his "perfectly controllable air-ship", and I declined to navigate it thus. He procured a hot-air-balloon-parachutist named Hogan, who, failing to make hy-

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drogen to fill it, next inflated it with coal gas (which lifts half as much), and forced a substitute for the large horizontal fan seen below. This fell off while in mid air, and the gas bag flew swiftly heavenward. The operator had neither ballast nor gas escape, and in the grasp of this monster was last seen 30 miles at sea, a victim of over-confidence in a too sanguine flying machine inventor.

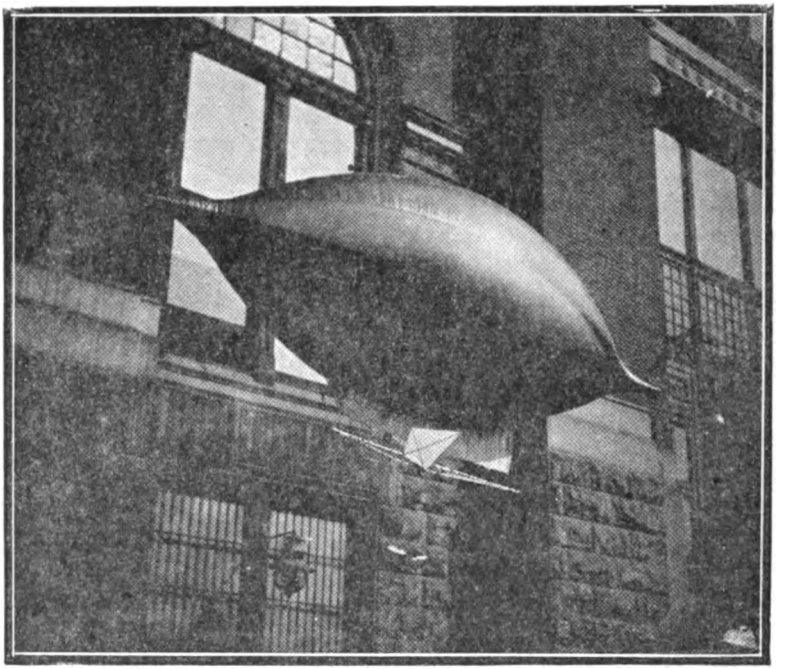

FIG. III.

The Pennington air-ship, of Chicago, was also built by me, so far as its hydrogen gas buoyancy chamber was concerned. Its defects were blunt ends, with a screw throwing all its air against the bow, and very large wings, rudder and keel, offering great resistance and the certainty of capsizing in a wind gust. So ignorant was the inventor that I had to double the diameter of the gas spindle, thus quadrupling its buoyancy, to construct a model 25 feet long to lift itself. His further ignorance was shown by his confiding to me his statement that he had discovered a gas lighter than hydrogen, "even lighter than vacuum."

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"What," I said, "lighter than nothing?" "Even so", he said. I could not argue with that man. His whole scheme was for floating stock and not for floating air-ships.

Up to a recent date the only other vessel for air navigation with a passenger, which has been publicly exhibited, is the so-called sky-cycle, designed and built by myself. This original mechanism, of 1878, is before you. Above it is the gas kite, a gas dome, like a split spindle, which partly supported it. Netting cords embracing this gas dome, (which is shaped like a capsized boat

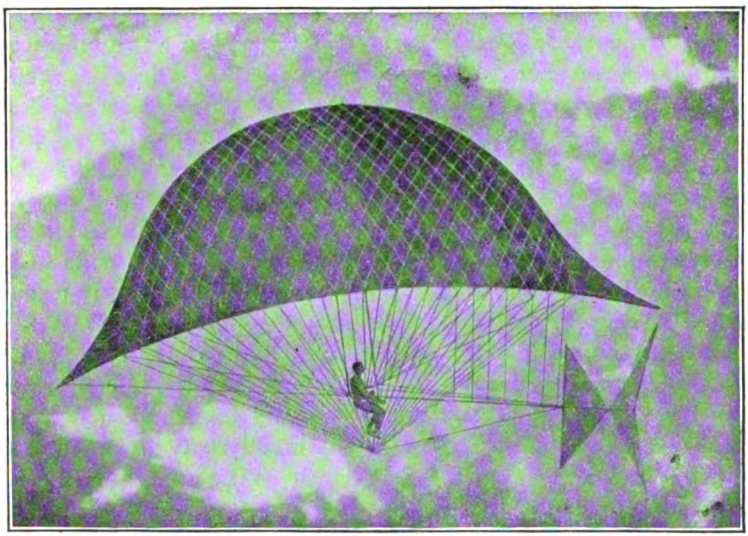

FIG. IV.

with flat deck down,) attach to the connecting ring, from which the tin saddle hangs. Seated here the rider clasps the hand cranks in front, while his feet turn the usual bicycle pedals below. This is the first chainless gear cycle ever constructed, and the gas kite is the first vehicle heavier than air which ever raised and carried man up and through the air by his own efforts, as it mounts slowly up an inclined plane pulled by the screw in front like any kite by its string. The waste wind is flung backward and beneath by this screw sail and to buoy the kite surface. Hand and foot cranks simultaneously revolve the screw shaft, and the action of the air twists the loose cloth sail into a helix. The rider leans backward to depress the stern and rise, and the vehicle slides downward and forward when the bow is depressed. Leaning to

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right or left tips and turns the machine in either direction like a common bicycle. Any fool can ride it. Landing is more difficult, in wind, because wind catches the umbrella surface underneath. Because of this, a complete gas spindle was substituted for safer control.

This is the skycycle. I beg you to note that it differs absolutely from every other model, in being round and plump amidships, with great gas capacity, while its prow and stern are of the utmost sharpness to pierce the air without resistance. I shall say more of this later. The gas spindle nearly lifts the machinery and its rider. It is steered up, down, right or left by these two aeroplanes, one on each side of me, which twist in wrist sockets like an outspread hand or fan surface. With the screw sail drawing forward and the front edge of each plane tipped up slightly you rise like a kite, and you dive down when you depress these advancing edges. If I place one plane vertical I stop the way on that side, like an oar dropped in water, and the whole machine revolves about this pivot, within its own length. Steering in any direction is simplicity itself. A dozen people have safely navigated it at altitudes from one hundred to ten thousand feet, traveled many miles, and landed at will without injury to man or machine. With it every known type of propulsion or guidance has been tested, and this identical machine has had nearly twenty years experimental use in practical aerial navigation by man power alone. It will do anything, slowly, or at the maximum speed of a running man.

It is not presented as the perfect air-ship, but as a successful experiment demonstrating by pioneer investigation how the successful air-ship should be constructed and operated. The various lantern slides following show some of its mid air flights and adventures.

To return to earth: The view before you is my "balloon farm" where various queer products are raised. The twenty odd objects on the lawn in front of the mansion are not gigantic mushrooms, pumpkins or pickles, but half-blown balloons, nearly ready to pick. Ten of these were oxy-hydrogen balloon bombs, built in five days, for the United States government rainfall experiments at Washington and Texas. Ordinarily, by old processes, it requires a month to build a single balloon. My swiftest rate, by my own system, was twenty hydrogen balloons in five days for General Greely, Chief of the Signal Corps, during the Cuban war.

Ordinary gas balloons are made of cloth cut in gores, sewed

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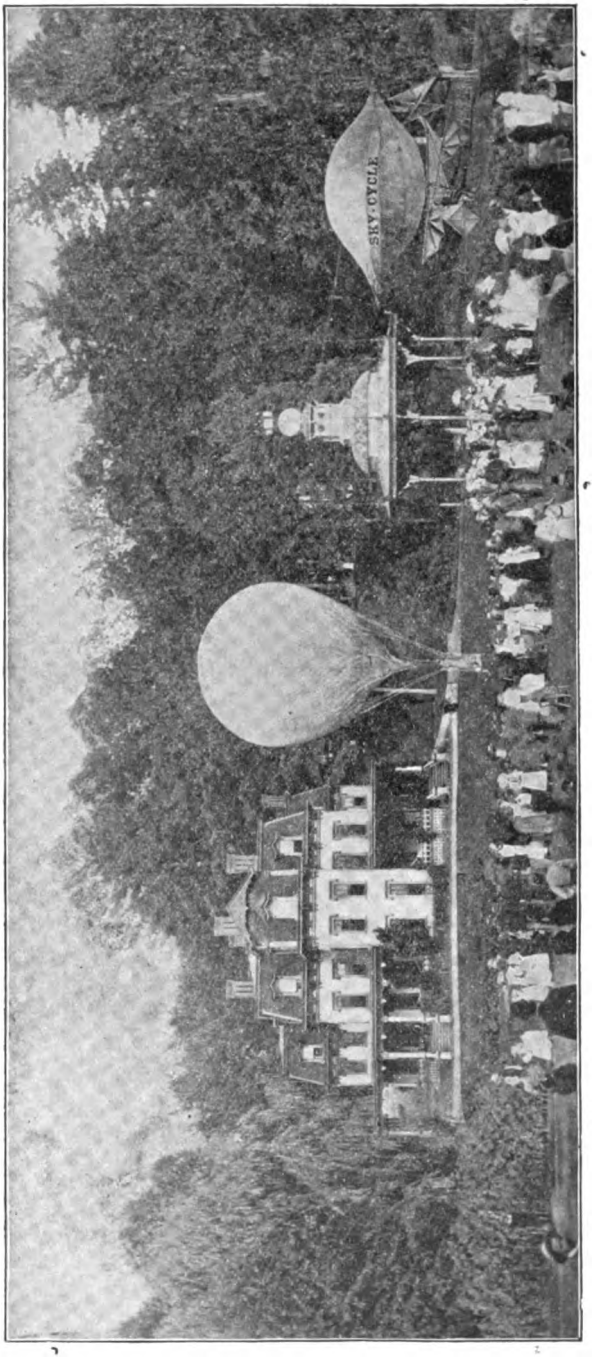

FIG. V.

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together and then varnished three, or at most four times, with broad hand brushes, producing a heavy, slow-drying, sticky balloon more or less porous to hydrogen.

I first built a machine to varnish cloth a dozen times, and dry it between coats. Each of these thin films was porous to hydrogen, but the multitude of them, over-lapping like shingles, tangled up the hydrogen molecules in the labyrinth of passages, and I later learned how to plug these microscopic pores in the film with the molecules themselves, as though coagulated within. Thus we have films too thin for a micrometer caliper to measure, yet impervious to hydrogen.

Much curiosity and doubt is felt regarding the success of the government rainfall experiments. I will detail the first test made at Washington, D. C.

A single bomb, ten feet diameter, was filled one-third full of oxygen,—the largest quantity ever previously generated out doors, with portable plant. The remaining two-thirds space in the balloon was filled with hydrogen from my usual portable generators, which produce each 1,000 cubic feet per hour.

When these mixed gases are fired, a most tremendous concussion results, millions of raindrops are produced, which may form nuclei for precipitation of aqueous moisture in suspension thereabouts.

The balloon bomb was held captive 1,500 feet high, on the outskirts of Washington. A percussion cap within the balloon was fired by a hand dynamo, or blasting machine on the ground, connected by duplex wires, from one uncovered joint of which I received an electric shock from the heavens as I let the balloon ascend.

I watched the little sphere with a good glass at the moment of firing. It instantly dilated to 100 feet diameter, a glowing globe of golden fire, like the sun moved near at hand. An instant later the space was filled with twinkling fragments of the balloon envelope, like snowflakes converging toward a centre. Then came an interval, and then the most terrific crash I had ever heard. Thunder in the mountains and the boom of heavy cannon seemed out-classed by this, the greatest bulk of oxy-hydrogen ever purposely exploded by man. The shock clattered down the vaults of heaven and reverberated for a period greatly outlasting that of ordinary thunder. The sky darkened like coming night and rain fell in torrents as we collected our apparatus and fled to cover. The little fishes in the brook lay dead in hundreds with upturned

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bursted bladders. The adjacent bowling alley of the Casino road house blew apart with its own air and blew together again with the recoil, like a house of cards blown down by a breath.

Next morning came a letter from Secretary Rust, of the Agricultural Dept., enclosing one from the chief clerk of the Smithsonian Institution, complaining that he and his wife had been witnesses to the experiments which had been violent beyond precedent, and, fearing for the safety of his family, and his herd of valuable cattle, he prayed that the experiments might be transferred to a more distant field.

As a result, after one more demonstration of the certainty of producing such concussions, using only weak charges of air and hydrogen for the benefit of department officials present in great numbers, we went in August to the "C" or Chicago ranch of Nelson Morris, 24 miles from Midland, Texas, an arid territory of 300,000 acres, with pastures 12 miles square, and cattle cheap. Here no dew or rain had fallen during the previous five months. Rain followed our first experiment, a week later, and dew continued five nights. At the end of August our final all day effort was followed that night by heavy rain, thunder and lightning on three sides of us, which entirely obliterated our return trail to Midland by washouts.

This digression illustrates only one of the many fields operated by me as an aeoronautical engineer, each one a novelty, and to pursue which properly and successfully demands as much scientific knowledge and expert training as any other branch of physical research.

To return now to aerial navigation and my own hobby, the sky-cycle. The culmination of my experiments in public occurred at the St. Louis Exposition of 1900, where, during five weeks, from Sept. 17 to Oct. 20, I made daily eight trips of thirty minutes each with my new sky-cycle and the electric aerial torpedo.

This was the first navigation of the sky-cycle, or of any man or woman in mid air, under a roof, and it was the first creation of the torpedo, which had no previous, combined, existence. The Coliseum at St. Louis, like Madison Square Garden, New York, has a roof 84 feet high and an oval arena 112 by 222 feet, surrounded by boxes and seats in tiers. Four different riders navigated the sky-cycle all over this limited aerial space, and around an electric fountain blocking the center like an island, quite as one might ride a bicycle on the ground, or skater on ice, and returned to the place of departure after thirty minutes run, exactly on time by a printed schedule and correct timepiece there.

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The electric torpedo, which you now see here, carried no rider. It is a symmetrical wave line gas spindle, 13 feet long, and 13 feet around its middle. It is a model dynamite air-ship, propelled forward by a 30 inch screw driven by an electric motor located in its keel boat, operated by a 110 volt direct current, controllable by an operator working this ten pole switch at any distant station. As moves the needle of this switch, so moves the air-ship in all desired directions, at varying speed like a humming bird or a dragon fly, in straight lines, curves, circles, cycloids, spiral ascents or vertical drops.

You notice as I tilt its keel toward you, the two aeroplanes midway between its center and its bow, having the same movements as the sky-cycle's guiding planes. There is also a rheostat on this gunwale and a row of magnets on the other, a tiny electric light upon its prow, and an anemometer behind to mark its speed. It ran nearly 700 miles within the Coliseum, whose limited space did not permit safely a greater speed than 12 miles per hour.

The sky-cycle is a pleasure craft, for individual use. The torpedo is a dynamite destroyer—an aerial projectile. With one or other of these two vessels over 100,000 printed tissue paper bombs were distributed as hand bills to the audiences during the five weeks daily exhibitions. At the close of the Exposition the General Manager, Mr. W. J. Atkinson declared that :

"Either of these air-ships in their present stage of development, in the hands of a man skilled in their use, and willing to take less than the ordinary risks of warfare could destroy any battleship or fortification in existence."

The daily use of two such air-ships, over a period of five weeks, was a daily oppprtunity to mature the future air-ship, on practical lines.

The immediately serviceable air-ship is the hydrogen gas spindle. It exists now, only needing demand and development in any line.

The basis of this is the symmetrical wave line spindle. It is demonstrable in theory and practice that this form experiences no head resistance in its passage through air. I have tested it, both as an air-ship and a projectile, more exhaustively than any other person.

It is derived in this way :—Upon diametrically opposite sides of a sphere I project cones having the same curvature as the sphere from which they spring, and converging in a sharp prow and stern, terminating in points, or at an angle of 0 degree. The re-

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sult is a simple wave line figure, spherical amidships, with incurved, hollow, prow and stern. Air moving past this merely undulates in waves recoiling upon the stern to urge the body forward, all pressure upon the figure being practically at right angles to the line of progress.

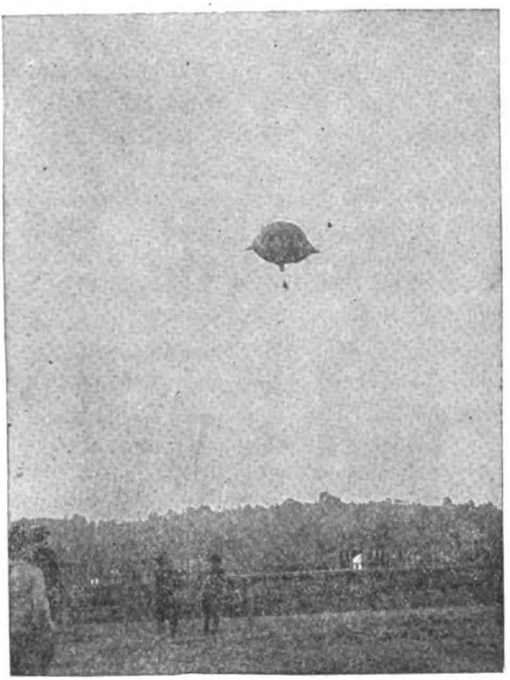

FIG. VI.

If we tow a toy hydrogen balloon by a string it oscillates at right angles to the line of progress in order to dodge the "chunk" of air crowded just in front. The symmetrical wave line spindle splits the air on all sides, like a wedge having a needle point, and the divided air returns upon the pointed stern with equal force to urge the body forward. Air is disposed to undulate, not like the surface of water, but in all directions at right angles with its progressive motion, compressing and expanding as it flows past obstacles. You may test this with a flag, placed vertically or horizontally in a wind; the flag and air harmoniously wriggle past each other with the least effort. These crude illustrations will serve; or you may wet an apple seed and project it between your pinching finger and thumb, as recoiling air pressure acts upon the

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stern of the "symmetrical wave line spindle". A shorter name would serve, but in no work on art or architecture, mathematics or mechanics is there known such a figure or descriptive name. It is unique as an air-ship, and we need no better form. I have tested it by projecting it in comparison with all known types of projectiles into air, water, sand, ice, wood, stone and metal, and it out-classes all the others in speed and limit of penetration; indeed, the modern type of projectile, with its bluntest angle in front and its stern sawed square across to "suck vacuum", is a "botch" in aerodynamics. What intelligent woman would sew with a broken or dulled needle? What man would shave with a razor without edge? What mechanic use a broken or dulled cold chisel? Try one of these blundering model projectiles in the same way!

I have been using the law of aerial undulations in my business since I first began air castle building. I inflate all my balloons with air to test them, without any machinery whatever to blow them full save their own undulations. The air desires to aid, if you give it a chance. So with the winds,—a useful factor in air navigation, transporting without cost, by generally constant streams; influenced by the country underneath.

For the future air-ship we require a vessel of superior form for buoyancy and swiftness, impervious to hydrogen, and braced with gas and air to preserve its form. We also require a reliable, light and powerful motor. So much has been achieved. We also require absolute control of vertical movement independent of altitude, and without loss of gas or ballast. This is accomplished by means I have practically tested, and it is now possible to construct and operate an air-ship of one-fourth the size of Zeppelin's monster, which may carry ten passengers 800 miles at the moderate speed of 20 miles per hour and remain up 40 hours without loss of equilibrium or horizontal level, and without renewed supplies, at a cost of one cent per passenger per mile. No such combination exists, but all the features do. I shall not build such an air-ship. It will cost too much money and the resources from existing aeronautical business will not yet warrant it. When demand requires such a creation, demand must create it.

This represents the position of actual aerial navigation to-day. My own investigations need the aid of youthful blood to continue, and the field opened is a profitable one for energy and skill. Air navigation is the heritage of the Youth of To-day.

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SHIPBUILDING IN THE UNITED STATES.

The Census Bureau has just issued a bulletin giving a mass of interesting facts concerning our shipbuilding industry, the growth of which during the past ten years, exceeds that of any previous decade; and the tonnage constructed during the census year was greater than during any preceding year in the history of the United States, with the possible exception of 1854 and 1855. The zenith of American shipbuilding, judged by the tonnage annually added to the merchant marine, was reached during the decade between 1850 and 1860. At that time the superiority of ships built in the United States, for endurance, speed and safety was generally conceded.

One remarkable feature of the growth of the industry during the past decade is the fact that the product of merchant vessels has been so largely absorbed and employed in the domestic commerce of the country. Comparatively few vessels for the foreign trade are now built in American shipyards. During the last four decades, therefore, the stability of the interest in the United States has rested almost wholly upon the domestic or coastwise trade, the vessels constructed for foreign trade representing but a small proportion of the entire output. The completeness of the decline of American shipping in the foreign trade may be briefly illustrated by quotations from the statistical history of the growth of the foreign commerce of the United States, showing the share in its carriage taken by American ships in the earlier years compared with the present time. In 1826 American vessels carried 92.5 per cent. of the foreign commerce of the United States, the value of which was $150,331,636, while in 1900 they carried 9.3 per cent., the value of which was $195,083,155, an increase in value of only 29.5 per cent. in seventy-four years. In 1826 foreign vessels carried 7.5 per cent. of our foreign commerce, valued at $12,238,163, while in 1900 they carried 90.7 per cent., valued at $1,894,445,461, an increase of 15,379.8 per cent. in seventy-four years.

In 1890 the American tonnage under register, in our foreign trade, amounted to 946,695 tons, since which time 206,771 tons have been built in the United States and documented under register, and 134,859 tons of foreigh-built vessels have been granted American registry. This would have made a total of 1,288,325 tons in 1900, had none gone out of existence. But in 1900 the tonnage was only 826,694, showing a loss of 461,631 tons during

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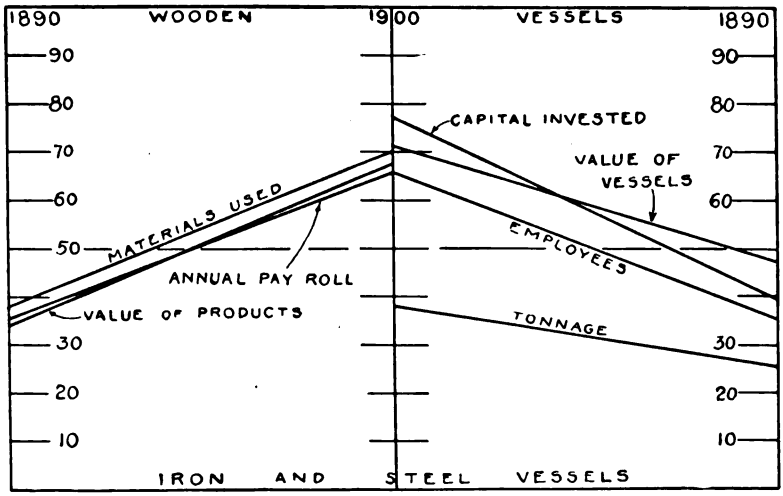
the ten years. This shrinkage is more than twice as much as the total new registered tonnage built in the United States during the decade. This indicates how hopeless, under present conditions, are the prospects of the shipyards of the United States maintaining even the present tonnage in the foreign carrying trade, to say nothing of providing the additional tonnage made necessary by the growth in volume of foreign commerce. An idea of the extent of this growth may be obtained from a study of the statistics of tonnage of foreign commerce entering the seaports of the United States in 1890 and 1900. In 1890 the tonnage of American and foreign vessels entering from foreign ports was 15,365,604 tons; in 1900 it was 23,533,597 tons, an increase of 8,167,993 tones, or 53.2 per cent. in ten years.

In spite of the discouraging outlook depicted above, the industry has made much progress during the past decade, particularly in the iron and steel branch.



An examination of the tables shows that whereas in 1890 wooden shipbuilding was the predominant feature of our total shipbuilding industry, iron and steel was now forged to the front, and is rapidly increasing its lead. This fact is clearly shown by Table III; and by the accompanying diagram, showing the percentage in which iron and steel shipbuilding is represented in the total.

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TABLE I.—IRON AND STEEL SHIPBUILDING.

	1900	1890	Increase %
Number of establishments	44	18	144
Capital invested	$59,840,000	$10,712,000	459
Employees, total	31,763	8,302	283
Salaries and wages	$17,643,000	$5,175,000	241
Cost of material used	23,586,000	6,257,000	277
Value of products and repairing	50,368,000	13,012,000	287
Vessels built	134	88	52
Gross tonnage	262,516	123,973	112
Value of vessels	$25,455,000	$11,551,000	120
Average tonnage	1,960	1,410	36
Average value	$190,000	$131,400	45

TABLE II.—WOODEN SHIP AND BOAT BUILDING.

	1900	1890	Increase %
Number of Establishments	1,072	988	8.5
Capital invested	$17,523,000	$16,551,000	5.9
Employees, total	16,425	15,101	8.8
Salaries and wages	$ 9,205,000	$ 9,395,000	*2.0
Cost of materials used	9,901,000	10,264,000	*3.5
Value of products and repairing	24,210,000	25,053,000	*3.4
Vessels built	1,953	1,265	54.3
Gross tonnage	425,165	360,667	17.9
Value of vessels	$10,301,000	$12,933,000	*20.4
Average tonnage	218	285	*23.5
Average value	$5,280	$10,210	*48.2
Small boats built	15,448	18,689	*17.3
Value of small boats	$1,973,000	$1,392,000	14.2
Average value	$128	$75	71.8

* Decrease.

TABLE III.—IRON AND STEEL SHIPBUILDING.

PERCENTAGES OF THE TOTAL INDUSTRY.

	1900	1890	%
Capital invested	77.5	39.3	97.2
Employees	66.	35.5	86.
Annual pay roll	65.8	35.5	85.4
Materials used	70.4	37.9	85.7
Value of products	67.5	34.2	97.4
Gross tonnage	38.1	25.6	48.8
Value of vessels	71.2	47.2	50.9

Table I shows that not only has this branch of the industry increased largely in all the essential items of information, but that the individual establishments have enlarged their productive capa-

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city by investments in improved machinery equipment, and by extensions of their plants. The capital per establishment increased from $595,000 in 1890 to $1,360,000 in 1900, or 128.5 per cent. The average number of employees to each establishment in 1890 was 461 ; in 1900 it was 722, an increase of 56.6 per cent. The average value of product per establishment was $723,000 in 1890, and $1,145,000 in 1900, an increase of 58.4 per cent.

Shipbuilding on the great lakes has assumed such proportions and is carried on under such peculiar conditions, as to make separate attention desirable. The eight establishments fitted for building iron and steel vessels in 1890 have not increased in number, but their combined capital has increased from $3,035,000 to $12,510,000, or 312 per cent. Employees have increased 152 per cent., from 2,590 to 6,528. Total wages, $1,389,000 in 1890, were $3,360,000 in 1900, an increase of 142 per cent. The cost of materials used has been augmented 126.5 per cent., from $1,768,000 to $4,004,000. The 33 vessels, of 36,728 tons, and valued at $4,128,000, have become 24, of 96,328 tons, valued at $5,183,628. This indicates an increase of 162 per cent. in tonnage and 26 per cent. in value. The tonnage per ship has increased from 1,113 to 4,014, or 261 per cent ; value per ship from $125,000 to $216,000, or 65 per cent. The value per ton has decreased, due to lower prices for steel and improved methods of construction, from $112 to $54, or 51.5 per cent.

SIBLEY COLLEGE GRADUATES.

The Secretary of the Sibley Faculty has prepared a statement showing the present condition of employment of the regiment of men who have graduated from Sibley College. This statement includes the records of all graduates from 1873 to 1900, inclusive, the number thus covered being 1183. Of this number 867 reported, 278 failed to report, and 38 have died since graduating.

In June, 1901, on which date the list is based, the average time elapsed since graduation was 6.9 years. The average alumnus, therefore, graduated in 1894 ; or, otherwise stated, these alumni, at the time of the accompanying report, had had on the average but 6.9 years in which to establish themselves in professional and business positions.

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SUMMARY OF POSITIONS.

	Total.	Production of Steel.	Construction of Steam and Gas Engines & Steam Boilers.	Railway Mechanical Engineering and Locomotive Construction.	Miscellaneous Manufactures.	Contracting Engineering.	Consulting Engineering and Technical Expert Work.	Supervision of Engineering Plants.	Naval Architecture & Marine Engineering.	Electrical Engineering.	Electric Railway, Light and Power.	Telegraph and Telephone Engineering.	Allied fields of Engineering work: Civil, Mining, Hydraulic, Gas and Architectural Engineering.
President of Company	10				6					1	2		1
Vice President	9		1		3	1	1			2	1		
Secretary or Treasurer or both	21		1	1	16					1	2		
Member of Firm or Proprietor	35		2		14	11	3		1	2			2
Superintendent, General Manager or Manager	99		3		48	5		3	1	9	21	2	7
Assistant ditto	20	3		1	10				1	1	1	1	2
Chief Engineer or Engineer	84		1		21		16	4		3	7	20	12
Assistant Engineer	17	2			8			1	2			1	3
Mechanical Engineer	90	5	6	10	44	19							6
Electrical Engineer or Electrician	91	1		1	10	4		5		48	21		1
Consulting Engineer	5								1		3	1	
Civil Engineer	4			1	2						1		
Expert or Laboratorian	11						2			9			
Inspector	13	4		2							4	3	
Chief Draftsman, Draftsman or Designer	120	5	8	11	48	4	1		25	12	1		5
Master Mechanic	4	2		1	1								
Assistant ditto	1	1											
Department Manager or Foreman	15	2		3	3					6	1		
Apprentice or Special Apprentice	24			15	2					6		1	
Mechanic	4			2	2								
Sales and Business Departments	33	2			14					11		6	
Teachers	87												
Miscellaneous	70												
Total reported	867	27	22	48	252	44	23	13	31	111	65	35	39
No report received 278													
Deaths 38	316												
Total Graduates	1183												

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Counting similarly from 1885, when the present form of Sibley College took shape, the number of graduates, to 1900 inclusive, is 1090, and the average time elapsed since graduation was 6.1 years. These alumni had had, therefore, but 6.1 years in which to establish themselves in professional and business positions.

The table shows the number engaged in the various kinds of businesses enumerated, as well as the position of each, in the several employments. Of the 87 men tabulated as engaged in the teaching profession, an unusually large number hold high positions, as shown in Table II. Table III shows the distribution of employment of the 70 men classed as miscellaneous. It will be noted that only one man is out of employment, and in his case the reason assigned is ill health. It is a fact, on which the Sibley College authorities may well congratulate themselves and the students who come under their instruction, that the list of unemployed Sibley College graduates is so decidedly short. The number of such graduates who are sufficiently dissatisfied with their present positions to be on the lookout for a chance to change is also gratifyingly small. The Director of the College is in receipt of far more applications for men than he can possibly fill, or than he can even hope to cover by recommendations of men whom he thinks may possibly wish to make a change from their present positions.

TABLE II.

Professors	35
Acting Professors	2
Associate Professors	3
Assistant Professors	11
Manual Training Director	1
Instructors	27
Assistants	2
Regents Examiner	1
High School Teachers	5
Total Teachers	87

TABLE III.

Officers of the Army, Navy and the Revenue Marine	8
United States Patent Office, and Patent Claim Business	12
Miscellaneous and unclassified occupations	35
Employment not stated	14
Unemployed by reason of ill health	1
Total miscellaneous	70

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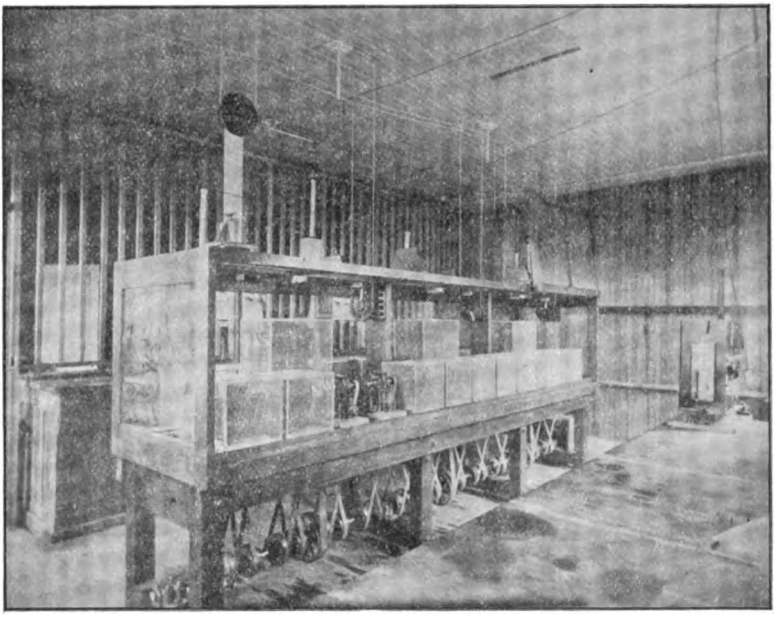
A 12,000-VOLT DIRECT CURRENT TESTING SET.

WILLIAM AMBLER, '00.

This apparatus, shown in the accompanying illustration, has recently been installed in the dynamo laboratory by the Departments of Physics and Electrical Engineering. The plant is original in a number of ways. The idea of using a number of generators connected so as to give this high pressure, and the manner of insulating and arranging so as to operate successfully, is due to Professor H. J Ryan. Heretofore, high direct current



voltages for experimental purposes have been obtained by means of electrostatic machines, or by the use of batteries, either primary or secondary, connected in series to give the maximum effect. A comparatively few secondary batteries might be charged while connected in parallel by the use of an ordinary pressure, and then connected in series for the discharge. These methods, however, either entail a great expense, if a power sufficient for proper experimentation is obtained, or else do not give a sustained

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voltage, but instead an intermittant one, the effects of which differ greatly from that obtained from a generator giving a constant pressure and which approaches most nearly practical conditions as well.

In the set there are twenty-seven machines in all, twenty-four of which are used to generate the high pressure current, while the other three are used as exciters to separately excite the fields. They were all made by the Crocker-Wheeler Co., being their standard type, with additional insulation. The exciters are each of ¼ H.P. capacity, designed to run at 1900 r.p.m. and to deliver 1.05 amperes at 175 volts. The generators proper are each of approximately ⅙ H.P. capacity, designed for 2500 r.p.m. with an output of .22 of an ampere at 500 volts. Both exciters and generators are run from a jack shaft driven by a 4 pole General Electric motor, not shown in the illustration, of the following rating: Capacity, 7.5 H.P., or 6.5 K.W.; volts, 500; amperes, 13; and speed, 850 r.p.m. This motor is connected through a starting box and a 25 ampere I.T.E. circuit breaker to the Sibley College 500 volt supply mains, and therefore can be operated independently of the rest of the laboratory. Two Kelvin electrostatic voltmeters for measuring the high pressure are to be used with the apparatus. These were made by White, of Glasgow, the smaller to give readings up to 8000 volts with 50 volts per scale division, and the larger to 18,000 volts with 100 volts per scale division.

The machines are arranged in groups both mechanically and electrically. One exciter supplies current to the fields of eight generators with armatures connected in series to give 4000 volts at normal field excitation. The fields of these generators are in series and hence each receives current at 22 volts pressure. A Crocker-Wheeler rheostat is connected in between each exciter armature and the generator fields, by means of which a very wide range in pressure can be obtained. Each machine is mounted upon a marble base and is surrounded, except at the bottom, by a galvanized iron wire cage of ⅜ inch mesh. The insulation of the fields was tested to stand 2000 volts each, while the armatures have only the standard insulation for 500 volts. The positive brushes of the generators are each connected to the surrounding cage, these cages being placed about ¾ of an inch apart. By this manner of connecting, the potential is not allowed to build up on any one machine, so that the ordinary armature insulation successfully withstands the pressure upon any one armature. The wire leads,

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to and from the machines, are all run in separate glass tubes passing through the marble base. The three groups of generators are connected in series to give the full potential. It should be noted that with this manner of connecting, any number of groups of generators can be connected, and consequently any desired pressure obtained. By the use of condensers, charged in parallel and discharged in series, a much higher potential can be obtained with the present equipment, though it is the intention to ultimately duplicate this set. The leather belts are found to be sufficient insulation between the pulleys of the different machines. All of the machines except the driving motor are mounted in a case of shellaced pine with glass sides, ends and top, to allow of proper inspection, cleaning, adjusting and lubricating, the sides being doors which swing upward on hinges along the upper edge of the case. The illustration shows the case with two of the windows removed and the further one on the side towards the observer swung up to allow access to the machines. Two of the generators are shown with their cages removed. The exciter rheostats are also shown upon the middle supports of the cage.

A very important part of the installation is the design and arrangement of switches and circuit breaker. These are placed in the top of the case and can be clearly seen in the illustration. These, together with the entire mechanical equipment, were designed and installed under the direction of Professor G. S. Moler and operate very successfully. The circuit breaker is similar to the ordinary direct current breaker in general principle. The arm separating the circuit contacts is released by a trigger operated by an iron plunger in the breaker coil carrying the main current. The height of the plunger in this coil was adjusted so that the breaker will operate at .24 of an ampere. As soon as released the arm is thrown upwards by means of a spring. The breaker is mounted upon a piece of marble, and great care was necessary in its design and construction so that the arc on the opening of the circuit could not jump across between points of different potential and thereby produce a short circuit. This arc is from five to seven inches long at 12,000 volts. There are two oil switches directly in back of the circuit breaker as seen in the illustration. Two are used so that experimental apparatus can be entirely disconnected from the testing set on both sides of the line to avoid risk of accident. The oil switches and rheostats are operated by means of pulleys and ropes passing overhead to the side of the room. The circuit breaker is reset in the same way.

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It is so arranged, however, that it is impossible to reset the breaker except when the oil switch is open. There is also an emergency switch in the main circuit of the large motor operated by a rope in the same manner so that in case of accident the entire apparatus can be stopped in a few seconds. Some such means of controlling the apparatus is absolutely necessary, for the greatest precaution must be exercised in its use; contact with any part of the set at this high potential being extremely dangerous. The following are some of the principal uses for which the apparatus will be employed:

Determination of the electrostatic gradient of air, and the dielectric strength of insulators to resist direct current pressures compared with alternating current pressures of various wave forms. It is expected that this will give valuable information in regard to the relative effect of mechanical strain as opposed to conductive currents on the breaking strength of insulators.

Comparison of the indications of high potential voltmeters on direct and on alternating current circuits.

Effect of corona on the breaking strength of insulators.

Comparison of the spectrum obtained with this high potential arc with other spectra.

Study of the relation between specific inductive capacity and the true dielectric strength of insulators to resist rupture.

Study of the combination of chemicals by use of the high potential break spark.

The discharge in vacuum tubes, and in air at atmospheric pressure.

The greater part of this experimental work will have a direct practical value in the design of insulation and transmission lines. Also by means of this apparatus a great many physical problems can be approached in a way not attempted heretofore, and undoubtedly valuable data will be obtained by its use.

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ON THE SPECIFIC HEAT OF SUPERHEATED STEAM.

The use of superheated steam in engines or turbines is becoming more and more general, and the determination of its specific heat for varying pressures and varying degrees of superheat becomes of ever increasing importance. Regnault, in his experiments on the specific heat of superheated steam, found the value to very closely approximate .48, the upper limit of his experiments being 226° C. (438.8° F.). It has lately been maintained, however, that the value varies with different pressures and different degrees of superheat, and experiments already made in this line, while not conclusive, seem to indicate the correctness of this statement.

Prof. Bach, of the Technical High School, at Stuttgart, in a communication to the *Zeitschrift des Vereins deutscher Ingenieure*, under date of May, 1902, brings to notice some conclusions from experiments made on the transmission of heat from steam to water, which also point in this direction.

The experiments mentioned were of two kinds: first, transmission of heat from saturated steam to water; second, transmission from superheated steam to water. The first of these gave entirely rational results, and hence are of no further interest in this discussion. But, in the second set it was found that the amount of heat found in the cooling water was invariably greater than that apparently lost by the superheated steam. Prof. Bach points out that, in view of the fact that some heat is always unavoidably lost from the water by radiation, conduction, etc., such results are all the more unexpected.

The formulae employed by him for computing the heat in steam were those given by the Society of German Engineers and other German societies in their "Code" of 1899.

For saturated steam, he gives, in metric units,

$$w_1 = 606.5 + .305t_1$$

for superheated steam

$$w_1 = 606.5 + .305t_1 + .48\,(t_1' - t_1)$$

where t_1 = temperature C, of saturated steam at the given pressure, and

t_1' = temperature C., of the superheated steam.

Holmes, in the "Steam Engine," gives a very similar formula, for saturated steam, English units,

$$H = 1146.6 + .305\,(t_1 - 212)$$

for superheated steam

$$H = 1146.6 + .305\,(t_1 - 212) + .48\,(t_1' - t_1)$$

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and it will be found on comparison that these formulae give identical results.

It is quite likely, then, that the discrepancies found by Prof. Bach are due to the inaccuracy of the expression .48 $(t_1' - t_1)$; in other words, that .48 is incorrect. This conclusion, however, must be offset by the fact that it is extremely difficult to obtain accurate heat measurements. There is also another point which may have some bearing on the question. It has been stated that steam, in passing from the condition of a saturated vapor to the condition of steam gas, (superheated steam), passes through a state where neither the laws of steam-vapor nor those of steam-gas are entirely correct. If this is the case, there might be a certain range of temperature, just beyond the critical temperature of the steam-vapor, where the specific heat of the superheated steam is materially different from the value at higher degrees of superheat for the same pressure. Further experiments on this line would prove just now very timely.

Prof. Bach gives the following computations based on his experiments. Taking the general formula

$$w_1 = 606.5 + .305t_1 + C(t_1' - t_1)$$

he substitutes the values observed in the different trials, and solves for C. The results are shown in the table.

Trial.	Temp. Superheated Steam. t'_1 °C.	°F.	Pressure Pounds Absolute.	Temp. according to Pressure. t_1 °C.	°F.	Superheat. $t'_1 - t_1$ °C.	°F.	Value of *C*.
1	325.9	618.6	37.0	128.0	262.4	197.9	356.2	.624
2	327.1	620.8	62.5	146.3	295.3	180.8	335.3	.574
3	325.6	617.7	91.0	160.5	320.9	165.1	296.8	.534
4	324.6	616.3	116.6	170.5	338.9	154.1	277.4	.536

It will be noticed that C is always considerably greater than .48. Its decreasing value is partly explained by the fact that, in each succeeding trial, the temperature difference between room and cooling water is greater than in the one before. This would tend to increase the losses by radiation, etc., and would cause the amount of heat found in the cooling water to decrease, this in turn decreasing the value of C.

Prof. Bach concludes by again calling attention to the fact that the above results were noticed in experiments which dealt merely with the transmission of heat, and states his belief that experiments made with the sole view of determining the specific heat of steam will show a figure close to .6.

H. DIEDERICHS.

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ELECTRICITY IN COTTON MILLS.

Under the above heading, W. B. Smith Whaley, '88, of Boston, presented a paper before the American Society of Mechanical Engineers, at its Boston meeting, May, 1902. The particular subject under discussion was the economy of an electric installation as compared with a mill driven in the usual way, with rope transmission and belts, and with a mill driven electrically, the power being furnished from an outside source. In the usual case the power-drop from the indicator cards measured 26 per cent. This includes all consumed energy other than that producing useful work, and may be termed the friction loss of the mill. In the

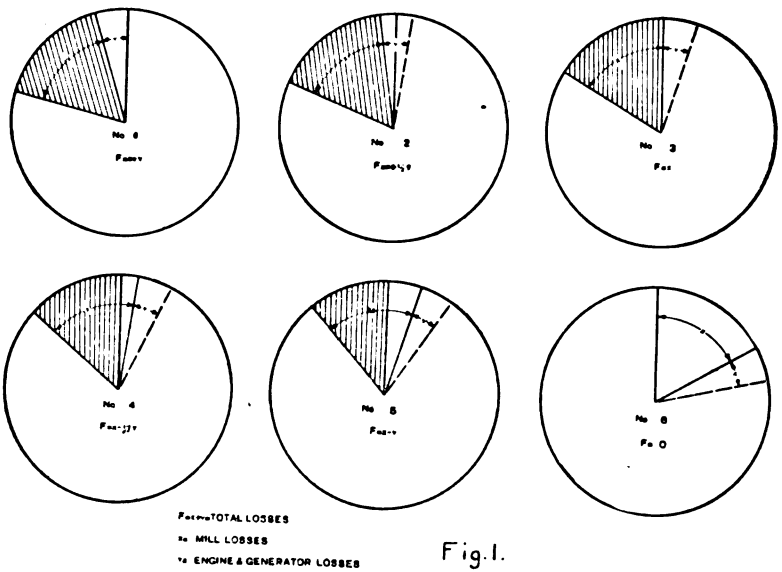

Fig. 1.

next case the power was measured at the switchboard, from which point a drop of 17 per cent was experienced, to the work produced. The difference of 9 per cent here noted might be considered to be due to the loss between the indicator cards and the switchboard. To determine what portion of this loss is actually here absorbed, and to get an idea of the general friction results, was the purpose of the investigation.

In order to graphically represent the conditions which apparently exist in these plants, Fig. 1 is shown, illustrating the con-

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ditions existing from time to time in the system. Assuming that the circles represent 100 per cent, then the losses due to friction, by which we will designate all energy other than that producing work, are shown by the angles x and y. x is all the friction and electrical losses from the switchboard to the work produced, and y from the indicator cards to the switchboard. In the tests the following course was pursued: The horse-power absorbed in running the engine and generator at speed without any current was measured, the two engines in use being indicated simultaneously at all times in order to annihilate any difference due to one engine leading the other in phase. The value of the total power of the light engine and generator without current is maximum y, and minimum y is shown on the tables of the horse-power and electrical output of the generator. y apparently vibrates from plus to minus. (In asserting y to be minus, it is not the intention to imply that there is no friction, but the system may, by the inertia of the shafting and machinery, return energy to the generators from the switchboard, when the generators tend to slow down. This is shown on the diagram in Nos. 4 and 5 by the fact that a part or all of y is subtracted from x, thus reducing the shaded portion. The apparent loss of energy between the indicator card and the point of application of the power is shown by that part of the diagram to the left of the vertical line.) The absorption of power as previously indicated can be readily followed from the six circles illustrating the different values of y and corresponding reduction or absorption of momentum energy in the system. It is possible under conditions of extreme lightening of the load to reduce the actual impulse of power to the generator for the short period of an absorption by the entire value of x and y. This, however, has never been the case in any observations taken.

The range of friction, as exhibited in values of y is from + 2.91 per cent to — 2.78 per cent; the average value of y seems to be very small (about .012 per cent), or, in other words, the reflex action due to the tendency to accelerate, which is checked by the step of the system, reduces the total friction by these amounts, and from the maximum in No. 1, of Fig. 1, to the possible minimum in No 6, there is a diminution which illustrates the absorption of this internal energy in the system.

In Fig. 2 are represented the conditions actually existing in the Olympia Cotton Mills at the time these tests were made. The individual tests were made, as far as possible, to cover the con-

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ditions of the motors in the mill. y on the generator circle marked A is taken maximum as shown in the horse-power differences, namely, + 2.91 per cent, and x is taken at its full value for mill losses. In the generator circle marked B, y becomes negative, and is taken at the lowest figure recorded, being — 2.78 per cent, showing the maximum and minimum values respectively as deduced.

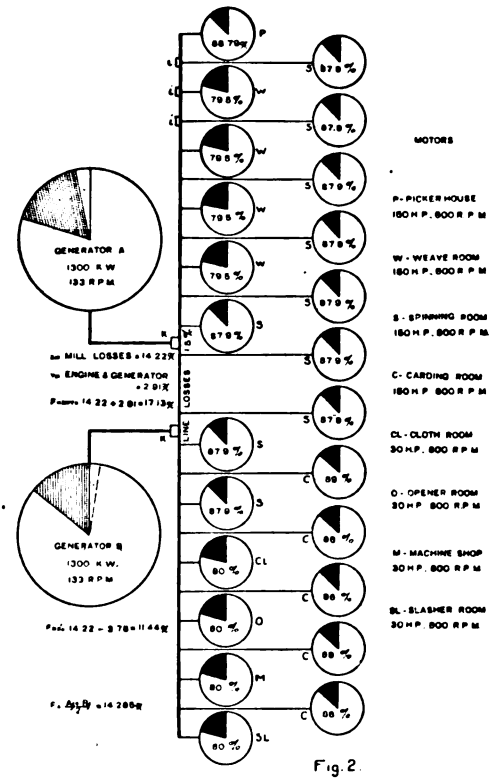

Fig. 2.

The average of all of the 60 tests gives an average for y, or assuming that the reduction of the engine and generator losses measures the reduction of total friction, the average for all of the cards will give us for this value of y, + .012 per cent as the value of generator losses, assuming that x is not diminished. As a fact the engine and generator losses remain practically constant and the diminution in the total friction is merely a reduction of the mill friction due to the generator action in the motors in the ap-

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parent acceleration effect, pumping back current into the lines and reducing the power taken to operate the system by this amount; as it is almost impracticable to measure this reduction in the mill, the only point where we can possibly detect it is in the indicator diagrams.

As may be seen in general outline, the generator is connected with the instantaneous reading wattmeter *K*, and the motors from the switchboard to the instantaneous reading wattmeters, *i*, *i*. From this data it appears that the friction losses in this class of work are far less than in any of the other methods of driving cotton mills, with an apparent efficiency which is indicated by every figure obtained from the Olympia plant at present as over 82 per cent net. With the average diminution of the total friction, the average friction on the plant apparently will not exceed 15 per cent for all purposes. A comparison of losses can now be drawn between the mills alluded to as follows:

Richland, from indicator card, 26 per cent.

Granby, from the switchboard only, 17 per cent.

Olympia, from the indicator card, $14\frac{22}{100}$ per cent.

PRESIDENT HENRY MORTON.

The recent death of President Morton, of the Stevens Institute of Technology, is an event which constitutes a serious loss, not simply to personal friends or even to the famous institution over which he presided for more than thirty years, but to science, and especially to the cause of higher professional and scientific learning. Every man of science, and especially every member of the engineering profession, will sincerely regret the loss of a man who was in his youth admittedly a genius, in early manhood a distinguished linguist and a famous lecturer in the field cultivated so splendidly by Tyndal, and was no less successful than the latter as a "popularizer of science". In the beginning of his career as a teacher he was admired for the clearness and brilliancy of his work. He quickly became marked for fame through his success in research and added to his distinctions by equally excellent work in the editorial chair of the *Journal of the Franklin Institute*, by studies of the fluorescence of the petroleum products, by the discovery of "thallene" and its wonderful properties, by many inventions of scientific apparatus, and by the accuracy and conciseness and clearness of all his published reports on his investigations.

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His special work, later, became that of pioneering in the field of higher and scientific learning and technical education, and particularly the establishment upon a high scientific plane of the profession of mechanical engineering through the organization of the first special school of that department, the Stevens Institute of Technology. In 1870, appointed President of that institution, he called about him some of the most able and earnest and promising scientific men of his time and began by organizing the school with the highest preparatory requirements then considered practicable and possible, and a four-year curriculum of the most advanced and thoroughly professional character then deemed by the leading members of the profession desirable or workable, and on a higher level than was then, or in fact is now, attained by the older professional schools, except in a few cases, where attached to the most advanced of our universities. This admirable position was maintained strictly and the curriculum was as strictly adhered to. No one could secure the diploma of the new school without having performed what at the time was considered to be an extraordinary amount of work of an advanced character, much of it mathematical, and all its professional details illustrative of the most advanced and approved practice. Adherence to this policy and to such a curriculum necessarily led to the graduation of a remarkably able class of young men, and their quality was soon recognized. The fame of the institution and the success of its alumni are thus fundamentally due to the wisdom, the originality, the courage and the discretion of President Morton, in the choice of a new field of work for his school, in his selection of strong men for its faculty, and in the construction and maintenance of a curriculum at the time without superior in any class of professional school.

For thirty years and more, President Morton stood at the head of this pioneer enterprise and maintained its policy firmly and consistently, yet with his eyes constantly upon the developments of the profession and of the schools, modifying the curriculum cautiously, but always in the direction of advance and in consultation with the ablest men among practitioners. He possessed a moderate fortune and was the recipient of a large income as legal expert in chemistry and physics and their industrial applications. He found his college cramped, financially, and began at a very early period in its history by contributing a very substantial part of his salary to its treasury and, later, gave many thousands of dollars, perhaps an aggregate of $150,000, for sustaining and extending its work. Mr. Carnegie, giving the engineering labora-

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tory and endowment, was the only contributor, during the life of Dr. Morton, who equalled or exceeded him in thus financially aiding that remarkable work.

Dr. Morton was as generous to dependents and poor neighbors and in the promotion of public movements of every desirable kind, as toward his own great enterprise. A similar union of genius, scientific attainments, culture, literary power and fine moral and social qualities has rarely been seen in our own or in any other country. He was at once a great, a good and a lovable man. As a founder of the highest class of professional schools of engineering, and a leader in their progress toward their splendid position among institutions of learning, he will probably be best remembered, and will remain famous even when his extraordinary personal attainments and his great scientific work have been lost sight of. Every thoughtful member of the profession, present and to come, will recognize in President Morton one to whom engineering will remain indebted for all time. R. H. THURSTON.

COMPARATIVE TESTS OF PLAIN AND PARA PNEUMATIC PULLEYS.

H. DIEDERICHS.

It has been claimed that at moderately high and high belt speeds a cushion of air is drawn in under the belt, thus preventing good contact between belt and pulley. This would result in a loss of adhesive power, and hence in effective belt pull, and greater slip. With a view of remedying this action, perforated and link belts, and perforated and grooved pulleys are employed. They all are supposed to give the air a chance to escape, and thus to maintain good contact between belt and pulley.

A late design of the perforated pulley is manufactured by the G. V. Cresson Co., of Philadelphia, Pa., and by them called the Para pneumatic pulley.

To determine the action of these pulleys in comparison with ordinary plain pulleys, some tests were recently made in the Mechanical Laboratory. The two sets of pulleys used were of iron, and were alike in their main dimensions, 24″ in diameter, with 8½″ face, slightly crowned. The construction of the perforated pulley is sufficiently well shown in the accompanying cut.

The tests were made on the Lewis belt testing machine, a description of which will be found in the transactions of the American Society of Mechanical Engineers, Vol. 7. The belt used was

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single leather, 34′ long, 3″ wide, and entirely new. Measurements made were those of power input and output, of tension in the belt, of slip, and of arc of contact. The belt speed averaged about 2.500′ per minute, and the maximum running tension reached in the belt per inch of width was about 129 pounds. It was deemed unsafe to proceed beyond this.

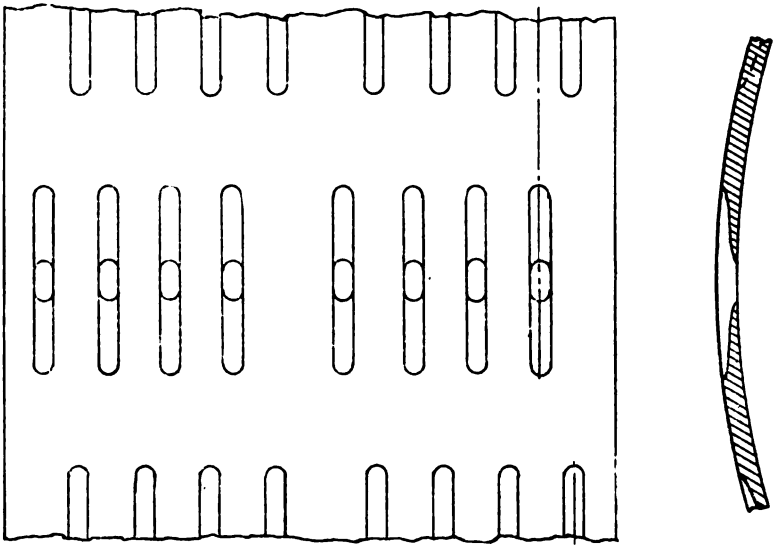

FIG. I.

The final results are shown in the accompanying curves. The pneumatic pulleys are seen to be superior to the ordinary throughout the ordinary range of belt tensions. The following tables show this superiority in several ways.

Initial Ten. Per In. Width.	HORSE POWER TRANSMITTED PER INCH WIDTH.								
	Slip 2%			Slip 3%			Slip 4%		
	Ord., a	Pneu., b	Ratio $\frac{b}{a}$	Ord., a	Pneu., b	Ratio $\frac{b}{a}$	Ord., a	Pneu., b	Ratio $\frac{b}{a}$
10	1.71	3.53	3.00	1.66	4.60	2.77	2.00	5.26	2.63
15	1.73	5.35	3.15	2.33	6.26	2.69	3.03	6.80	2.24
20	2.73	6.46	2.45	3.53	7.33	2.08	4.46	7.86	1.76
25	3.83	7.13	1.87	4.80	8.00	1.67	5.76	8.53	1.48
30	4.86	7.53	3.55	5.83	8.26	1.42	6.73	8.70	1.29

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The above table shows that the gain is greatest with the lower tensions and smaller slip, and that it gradually decreases as the initial belt tension and the slip increase. This point is also very strikingly brought out by the curves. Extending these, as is shown in dotted line for two of them, it will be seen that they approach each other more and more closely. The indications would seem to show that at some high belt tension the superiority of the perforated pulley would disappear, probably due to the fact that the extreme tension excludes the air cushion. It may even

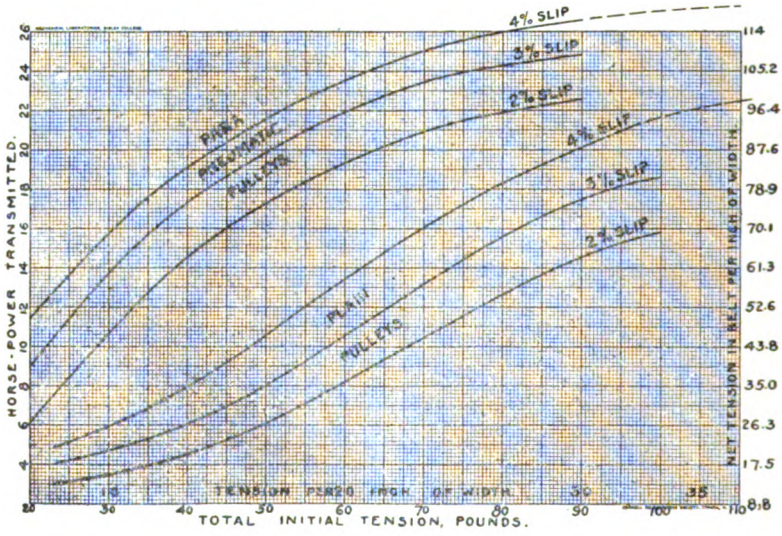

FIG .II.

be supposed that at and beyond that critical tension they may be somewhat inferior to the plain pulley on account of the decreased surface in the face. The fact that the gains decrease as the tensions increase negatives the statements sometimes made that the increased transmitting power of perforated pulleys may be due to the fact that the belt slightly settles into the perforations. If this were the case, we would expect an increase of gain at the higher tensions. The critical tension above mentioned is greater than any that is likely to be used in ordinary work, and the fact of its existence can not affect the practical utility of the pulley to any extent.

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Another striking way to bring out the advantage of the perforated pulley is to compare the initial belt tensions required to furnish the same horse power at the same slip for the two kinds of pulleys. This is done in the following table.

Horse Power Per In. Width.	INITIAL BELT TENSIONS. POUNDS PER INCH OF WIDTH.								
	Slip 2%			Slip 3%			Slip 4%		
	Ord., a	Pneu., b	Ratio $\frac{b}{a}$	Ord., a	Pneu., b	Ratio $\frac{b}{a}$	Ord., a	Pneu., b	Ratio $\frac{b}{a}$
2	16.5	6.6	.40	—	—	—	—	—	—
3	21.2	8.8	.41	18.0	6.6	.37	—	—	—
4	25.6	11.2	.44	21.8	8.8	.40	18.5	7.5	.41
5	31.0	13.8	.45	25.8	11.0	.43	22.0	9.4	.43
6	—	—	—	31.3	14.0	.45	26 2	12.0	.46
7	—	—	—	—	—	—	31.6	15.8	.50

It appears from this table that the belt tension necessary with the perforated pulleys was in only one case as high as one-half of that required to transmit the same power with the same slip with the plain pulleys. In all of the other cases it was considerably less. This fact allows of the running of much slacker belts with the pneumatic pulleys, securing all the advantages that this implies.

In conclusion, it must be borne in mind that, with belts of different widths and weights and with different speeds, the results will probably be somewhat different, but it is quite reasonable to suppose that the relative positions of such results will not be changed, and that there should be therefore a field of useful application for these pulleys, especially at high and moderately high belt speeds.

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THE BRAYTON CYCLE.

As a matter of interest to readers of the SIBLEY JOURNAL we insert cuts of indicator cards taken from the Brayton gas engine, in the laboratories of Sibley College, using gasoline as a fuel. These cards showing the Brayton cycle, closely resemble steam engine cards from an automatic engine, and are quite different from cards obtained from ordinary gas engines. The horizontal "admission" line shows a slow burning of the fuel which is brought about in the following manner:

A mixture of vaporized gasoline and an insufficient supply of air is fed continuously into the cylinder through a wire gauze, and, upon starting, is lighted inside the cylinder. A valve, regulated by the governor, admits air under pressure and causes a more rapid and complete combustion of the gasoline until the valve closes, that is, until "cut off," after which the products of combustion expand until the exhaust valve opens. The flame in the cylinder is never extinguished, being kept burning by a small supply of air, regulated by a by-pass around the main air valve.

The engine has two cylinders, one, the working cylinder, 8″ x 12″, and the other, 8″ x 6″, is an air-compressor for compressing the air supply into the receivers. Cards were taken from each of these cylinders, but so long as the receiver pressure was constant, the cards from the air cylinder were not affected by a change in load. When these cards were taken the receiver pressure was held constant at about 55 lbs. gauge, and the load on the engine varied by a brake to show the effect of load change upon the card.

The governor was of the fly ball type, operating the "admission valve" through a cam, the position of which determined the *time* the valve was open; the valve always opening in full.

On the cards is given the net I.H.P., which is the difference between the I.H.P. of the working cylinder and the I.H.P. of the air compressor. The scale of the springs used was 60 lbs. to the inch, for both cylinders. The governor held the speed at an average of 196 R.P.M. The cards are shown full size.

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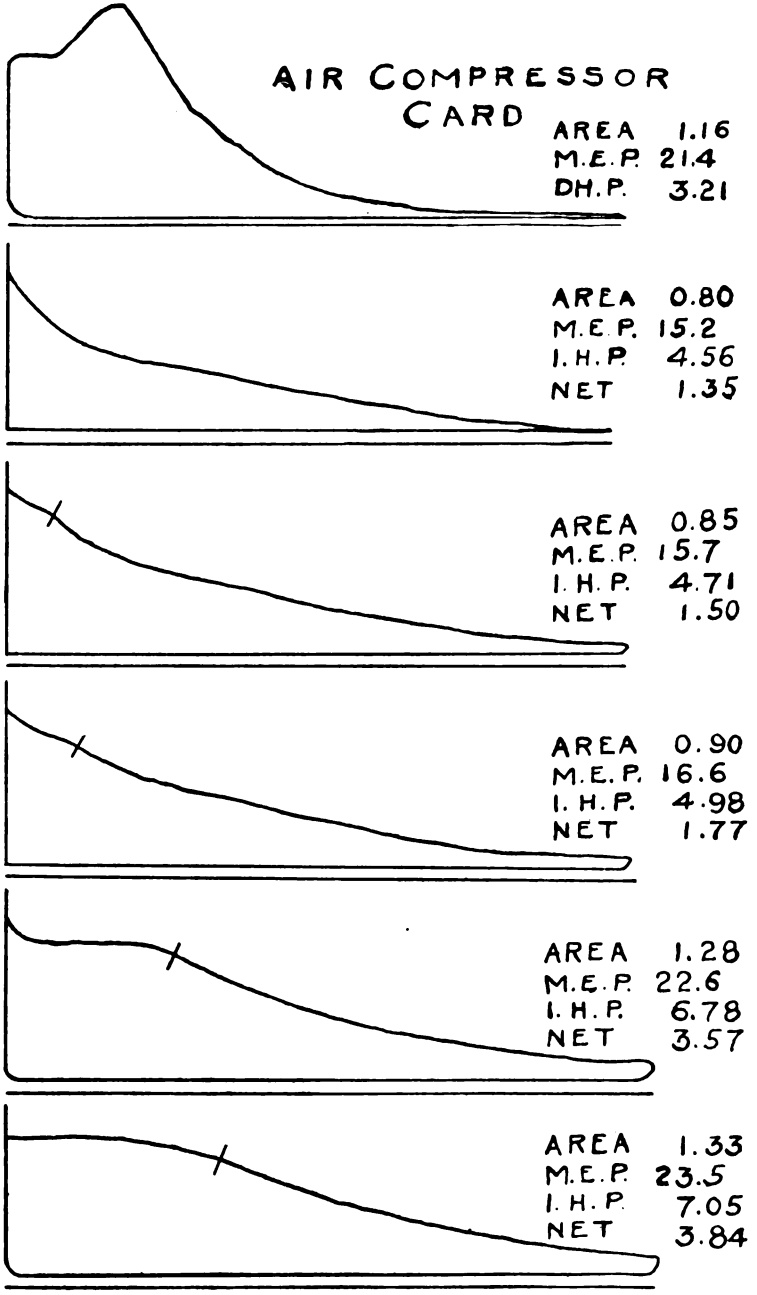

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THE SPRAGUE MULTIPLE-UNIT SYSTEM OF ELECTRIC RAILWAY TRANSMISSION.

Under the above title, Professor William A. Anthony, of the Cooper Institute, of New York, formerly Professor of Physics and head of that department in Cornell University, a pioneer in the field of Electrical Engineering, and founder of the world-renowned course in that profession in Cornell, addressed the students of Sibley College, on May 23d, 1902.

He opened his address by a few remarks of an historical character, concerned with the early and marvelous development of the electric railway. It was in 1887 that Richmond, Virginia, witnessed the installation of the first electric traction system in the world, and in 1898, only eleven years later,,the original ten miles in Richmond had become 15,672 miles for the United States, with 36,429 motor-cars and 7,914 "trailers." Electric traction may be conveniently and naturally subdivided into three classes of service :—single motor cars operating independently, with which every city in the United States is familiar ; electric locomotives drawing trains of cars, themselves unequipped so far as power appliances are concerned ; and trains of cars, all properly equipped and capable of independent action, but working in a "multiple-unit." It was the equipment of the latter type which occupied the attention of the lecturer.

The Sprague system, whereby all the cars may be operated from a single station on any one of them, was explained at length, by means of lantern slides, as well as by aid of a full-sized working model of the complete equipment for a car. Several diagrams of the wiring were shown, and the various parts traced from the screen to the model. The motorman's switch-controller is contained in a case not more than one-fourth the size of that required for the ordinary controller at present in common use. The first thing that happens when this switch is thrown over is the adjustment of the reversing coils for moving in the desired direction. Then the "pilot" motor attached to the main resistance coils operates to cut out enough resistance to allow the passage of the starting current, after which the motor picks up speed in the usual manner. It is impossible, with this system, for the motorman to burn out the motor by throwing on too heavy a current before it gets up to speed, as the pilot motor acts with sufficient deliberation to prevent any such accident. It is likewise impossible to

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run the car backwards at more than one-half speed, though by going to the other end of the car, full speed may be obtained, in the desired direction.

A magnetic "throttle" or relay is provided, which prevents one car of a train from doing all the work of traction, in case that work would cause an excessive amount of current to pass through its motors. This prevents any bad results which might accrue from the action of the pilot motor on one car picking up more rapidly than on the other. Another safety device operates whenever the circuit is broken, as when the trolley slips from the wire. It throws the main resistance all in, as at the original starting; then, when the current is re-established, the pilot motor "picks up" as before. A spring on the controller handle requires the motorman to keep it continually under his hand, under penalty of its swinging back and stopping the car. A number of other devices, mainly intended for greater safety or ease of manipulation, were shown. When two or more cars are operated together, they are connected (electrically) by means of a flexible cable containing no less than seven conductors. The joints or ends of this cable are so constructed that it is impossible to get it connected in any way but the right one.

In conclusion, views were shown of trains on the South Side Rapid Transit line in Chicago. One such train contained fourteen cars. The required current through the switch controller being about one ampere per car, and the capacity of the controller 25 amperes, it follows that trains up to 25 cars can be operated on this multiple-unit system.

In the March number of the SIBLEY JOURNAL was published an important paper by Mr. F. A. Halsey, editor of the *American Machinist*, on "The Premium Plan of Paying for Labor," which is regarded by its author as the most complete exposition of his well-known views on the subject that has yet been published. This paper has been reprinted, and a limited number of the reprints are still on hand, selling at fifty cents each.

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SIBLEY COLLEGE—AN APPRECIATION.

ITHACA, N. Y., May 22, 1902.

Gentlemen of the Faculty of Sibley College: —

I don't wish to leave the University, or better, Sibley College, without expressing my sincere thanks to the honorable professors of the Mechanical Department, and to express to them my gratitude for the kindness they have always shown me in spite of the trouble given them during my stay at the College.

Very probably, so far as I know, I am one of the first Swiss who came to Ithaca to pluck some fruit from the big Sibley tree, and who enjoyed it. The friendship and attention which always was given me shall not be lost, and I can only prove my gratitude by speaking always very highly of your institution to my European friends and acquaintances, so that many more Swiss or Europeans will come to Sibley College to study. I shall speak of your institution so that it shall be looked upon as being a model of modern technical schools, where theory not alone is taught, as is the case in European Polytechnical schools, but where theory goes hand in hand with practice. The better known a college is the more important it becomes, and to get so far it must not only be known in its own country, but among foreign countries. And this is made possible by having at the institution professors who are authorities in their subjects and by having as many foreign students as possible. As stated before, I shall take pleasure to give your institution a good name among my countrymen in Europe.

Zurich, the well-known Polytechnical school, which has a name in the world, has not only become known by having professors who are authorities, but also by the fact that the school has been organized in such a way that it is open to all classes, and to students of all nationalities. The tuition is fixed at 150 francs per year for all mechanical courses. The student number at the mentioned Polytechnical school was about 1370 in 1900, 935 regular students and 435 special students.

This table shows how Zurich Polytechnic has students from all over the world, 40.85 per cent. being foreign students. This does not include the students of the University as a whole, where the percentage of foreign students to Swiss is rather higher than at the Polytechnic school.

Now the question may arise, if this institution is so well known, if this institution stands so high, why should a student like to come to Sibley College; what would he expect to find here more

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LIST OF FOREIGN STUDENTS AT ZURICH IN 1900.

Austria-Hungary	90	Luxembourg	8
Germany	68	Denmark	6
Russia	38	India	6
Italy	34	Greece	5
Roumania	23	Servia	5
England	21	Turkey	4
America	20	Bulgaria	3
Holland	19	Belgium	2
Scandinavia	19	Portugal	1
France	9	Spain	1

Total foreigners	382
Swiss	553
Students	935

than at the Polytechnic? He would find a good many things here that he cannot find there and things that are absolutely necessary to an engineer. He will find here practice; he will find the shops, which are nowhere to be found in an European Polytechnic school, and he will find here the mechanical laboratory which is an ornament to your College. The Zurich Polytechnic school has a mechanical laboratory, which is one of the finest in the world. But, unhappily, I am sorry to say, it is too fine; so much so that students are not allowed to touch or work on any of the most modern machines. They are and can only be run by trained or paid engineers. A steam-engine test will be made by students; but they are only allowed to take the steam diagrams, the engine being run by a paid engineer. But it is much more important for a student himself to run an engine, to take it apart so as to get well acquainted with the different parts and their functions, even if the engines are not of the most modern type. It is also known that students at the Polytechnic are allowed very little work in the mechanical laboratory, so that Sibley College has cause to be proud of its mechanical laboratory, which is the only one in the world offering so many opportunities for a student to become familiar with different machines.

Why don't European Polytechnic schools have shops? Financial reasons? No, the idea of the European Polytechnic is this: — A young man who wishes to learn practice is only able to learn it in a manufactory. It is not possible to teach a man practice by theoretical ways and methods; he can only learn it on a practical basis. In regard to this, if we have shops, where trained mechan-

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ics would be at the head and teach the young men practice, this could only be done in theoretical ways. The young man is surrounded by young men as unpractical as himself; his left neighbor is teaching him the most unpractical way to do a thing, his right neighbor the same. He is surrounded by unpractical men who can't teach him anything and from whom he will learn nothing; while in a factory, practice is taught on other princicles, and that is the only place where it is learned right.

Professor C. Bach, who is well known as being an authority in Germany, says in his book, *Machienen-Elemente* that a student expecting to attend a Polytechnic school ought to have at least one year's experience before entering. This has been required since 1883 at the Polytechnic school at Stuttgart; and this is the only way to do, if a student wants to go through an European Polytechnic with success. We may now ask whether this is the best?

I think that when a young man, after going through a high school, is able to leave his studies and work in a factory for one year without forgetting too much of his theory, and then attend Polytechnic, it is the best thing to do. In this case our Polytechnic stands very high and is certainly very good. The young man having practical ideas will understand the theory much better and will apply his theory to his practical knowledge with much better success. He will apply and combine practice with theory through all of his work, as for instance in the drawing-room, etc. But, if a young man, on account of money or time, is not able to give up his studies for a year to work in a factory before entering Polytechnic, it certainly would be much better for him to attend a school which has shops like Sibley College. The results obtained at Sibley College show the success of such shops.

Besides this, I would not forget to mention the good relation and friendship existing between American professors and students. In that, Sibley College seems to me as being a big commonwealth in which everyone shares alike.

I end by expressing once more my thanks to the professors of the Mechanical Department of Sibley College and by wishing Sibley College a glorious future.

I have the honor to remain,

Yours very respectfully,

PAUL E. BRANDT.

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A BULLETIN of the United States Geological Survey, dated Apr. 17th, 1902, refers to Refined Current Meter Experiments at Cornell. The recent experiments conducted at Cornell by Professor E. C. Murphy for the U. S. Geological Survey, which indicate the variations of current meter measurements and their relation to measurements of flow obtained from weirs are of interest.

The velocity measurements of a stream from which the daily and monthly flow are computed are now universally made with some form of current meter. This instrument does not give directly the velocity, it simply indicates the number of revolutions in a given time of its revolving wheel. Before the velocity of the water can be obtained, the velocity which produces a given number of revolutions per second must be determined. In other words, the meter must be rated before the revolutions indicated by it can be converted into velocity. A meter is rated by dragging it through still water at different speeds and counting the corresponding number of revolutions of its wheel. In using the meter it is held rigidly in a fixed position and the water flows past it. The question arises, is the relation between velocity and revolutions when the meter is dragged through still water the same as when the meter is held at some point below the surface and the water allowed to flow past it?

The U. S. Geological Survey is seeking an answer to this question by a comparison of the discharge of the Cornell experimental canal, obtained with current meters, with that obtained by a sharp-crested weir. The true mean velocity of the water flowing in this canal is obtained from the head on the weir; the mean velocity of the same volume is measured with current meters, using still water ratings of the meters. If the mean velocity shown by the meter is the same as that shown by the weir, then the relation between velocity and revolutions of meter wheel is the same when the meter is dragged through still water at a given speed as when the meter is held at a point of mean velocity, and water of this velocity allowed to flow past it. These experiments indicate that for velocities greater than one foot per second, the meter velocity is less than the weir velocity, and that the difference between the weir and meter velocity increases as the velocity decreases. The mean velocity has also been measured with float rods as a check on the work. The velocity shown by the rods agrees closely with that shown by the weir.

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THE SIBLEY JOURNAL OF ENGINEERING.

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THE SIBLEY JOURNAL OF ENGINEERING,
ITHACA, N. Y.

WE take pleasure in announcing the election to the 1902–'03 Board, of Ralph S. Cooper, '03, and Walter H. Kniskern, '04, from their respective classes, and Clarence A. Dawley, '04, as the result of competition. The 1901–'02 Board has elected to the new Board Horace E. Sibson, '03, and Rudolf E. Mueden, '03. The new Board has organized by the election of Mr. Mueden as Editor-in-Chief, and Mr. Sibson as Business Manager. A graduate editor will be elected in November.

MANY of the JOURNAL'S subscribers have as yet failed to appreciate the fact that it is necessary for us to have all subscriptions paid promptly in order that we may meet our obligations. Those who have not yet settled for this year's JOURNAL will confer a favor by doing so at once, either personally or through the medium of the mails.

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THE following men from Sibley College have been elected to Sigma Xi :—

Graduates :—
L. D. CRAIN, B.M.E.
NUMA REID STANSEL, B.S., E.E.,
Seniors :—
RAYNER MONROE BEDELL.
HERMAN GEORGE BREITWIESER, B.S.
ORIN B. COLDWELL.
WARREN BEEBE FLANDERS.
ALAN ESTIS FLOWERS.
CLARENCE JEREMIAH GOMPH.
RUD BRYANT HAYES.
SAMUEL PURDY HOWE.
ROBERT AUSTIN IVES.
HAROLD EDDY JOHNSTON, B.A.
SIDNEY GRAVES KOON.
WALTER JOHN MAYTHAM.
ALBERT SILAS PENNEY.
SAMUEL MATTHEWS VAUCLAIN, B.S.
EMERY LAFAYETTE WALKER.
ALBERT WALTON.
EDWARD LYMAN WILDER, A.B.
SHIRO YAMAZAKI.
JOHN M. YOUNG, B.S.

It is suggested to the alumni and friends of Sibley College that if any one among them happens to possess a copy of any painting or engraving suitable to hang on the walls of the new museum or auditorium of Sibley College, if it could be secured, it would be a most acceptable accession to the collection of the college. Such, among engravings, would be the engravings by J. Scott, of Lander's painting of Jas. Watt and his engine-model, published by H. Graves & Co., London, or the engraving by Sartain, of Schussele's painting, "The Iron-worker and King Solomon," published by Bradley & Co., Philadelphia.

Electrical World and Engineer is authority for the statement that Dr. A. E. Kennelly, of New York, a frequent and popular lecturer before Sibley College, has accepted the newly founded chair of Electrical Engineering, at Harvard University.

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The amenities which have long existed between Cornell and Vassar have been recently strengthened by the exchange of courtesies between the Vassar Sophomores and Sibley College. The class-seal was modeled, as a medal some six inches in diameter, in the art department of Sibley College, and was cast in bronze in the foundry, for the purpose of marking the "class-tree" of "'04." It is reported to have been a great success and the contributors to its production are as much pleased as are the recipients of this testimonial and of this evidence of artistic ability, as well as of the fraternal feeling toward Vassar existing at Cornell. It is hoped that the bonds uniting the two colleges may become more numerous, as time goes on—and closer.

Department Notes.

There is at present under construction in the quadrangle bounded by West Sibley, the machine shop, the locker rooms and the boiler house a small concrete building which is destined to serve as a shelter for the two big steam pumps described in the February number of the SIBLEY JOURNAL. These will be connected with the boilers, on which steam is kept at all times, and, on the other hand, with the water mains, thus forming the basis of a much-needed fire protection on the hill.

Personals.

'87. William S. Elliot, E.E., is agent for the Stirling Boiler Co., Germania Bank Building, Pittsburg, Pa.

'91. Charles M. White, E.E., is an electrical engineer with the White Electric Company, contractors and dealers in electrical supplies, 166 Allen Street, Buffalo, N. Y.

'92. Stuart G. Barnes, M.E., is an electrician in the employ of the Solvay Process Company, at Detroit, Mich.

'93. Wilbur F. Evans, M.E., is manager and treasurer of the Electrical Maintenance and Supply Co., Boston, Mass.

'94. Martin Hughes Gerry, Jr., M.M.E., has, since graduation, been connected with the Sprague Electric Railway Company, the Thomson-Houston Company, the General Electric Company, the West Side Construction Company of Chicago, the Northwest

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Engineering Company and the Helena Water and Electric Power Company, now known as the Missouri River Power Company, of which he is Chief Engineer and General Manager. The large power plant of this company supplies electric power to the cities of Butte and Helena, Montana. The transmission to Helena (18 miles) is at 12,000 volts; to Butte (65 miles) at 50,000 volts. Mr. Gerry is a member of the American Institute of Electrical Engineers, American Society of Civil Engineers, and the Western Railway Club.

'95. Andrew G. Croll, E.E., is in charge of the draughting room of the Atlas Portland Cement Company, at Allentown, Pa. H. A. Wiltse, M.E., '00, is in this office.

'96. William Logan Benitz, E.E., now Professor of Mechanical Engineering, at the University of Notre Dame, South Bend, Ind., has just been appointed City Electrician of South Bend. He is rejoicing over the arrival of a son, who first saw the light on March 25th.

'98. Volney Nelson McCarn, E.E., has left the employment of the Metropolitan Street Railway Company, of New York City, where he was working in their 96th Street station, and has gone to Kansas in search of health. He expects to spend the summer on a ranch.

'99. John S. Avery, E.E., Editor-in-chief of the 1898–'99 SIBLEY JOURNAL, has relinquished his position with the Heine Boiler Company, to assume the General Managership of the Rockland Light and Power Company, of Nyack, N. Y.
Sharon, Pa.

'99. F. H. Eastman, E.E., has left his position as electrician of yards and docks at the Brooklyn Navy Yard, to accept a position with the Crocker-Wheeler Electric Co., at Washington, D. C.

'99. Henry N. Sporborg, E.E., has gone to England to accept a position with the British Thomson-Houston Company at Rugby, where he will be employed on railway electrical work. He was married on the 12th of May to Miss Miriam A. Snaith, of Syracuse. Their home in England will be at Rugby.

Ex.-'01. Claudio J. Martinez has recently installed on a private railroad on his father's Hacienda de Hornos, near Torreon, Coahuila, Mexico, a locomotive which he constructed in the machine shop of the hacienda. It is of 18 horse power, and made a completely successful trial run of 23 kilometers, with ten cars attached. This is said to be the second locomotive built in the Republic of Mexico.

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'01. Charles C. Remsen, E.E., is assistant to Mr. Mandelick, constructing engineer of the Sprague Electric Co., in New York.

'01. Isaac H. Francis, Jr., M.E., has been transferred to the Baltimore office of Henry Adams, M.E., consulting engineer, of which office he now has charge.

BOOK REVIEWS.

Theory of Steel-Concrete Arches, and of Vaulted Structures. By William Cain, M.A.S.C.E., Professor of Mathematics, University of North Carolina. Second edition, thoroughly revised. New York: D. Van Nostrand Company, 1902. Pp. 181 + xli. Price 50 cents.

Under the four chapters are discussed "Arches of Variable Section under Vertical Loads," "Culverts and Tunnel Arches," "Joined and Cloistered Arches," and "Domes of Masonry." The book is thoroughly technical in its nature; free use has been made of the calculus, where necessary. A number of graphical solutions to problems are given, and altogether 24 illustrations are used to supplement the text.

L'Electricité à l'Exposition de 1900. Published with the assistance and under the technical direction of MM. E. Hospitalier, editor of *l'Industrie électrique*, and J. A. Montpelier, editor of *l'Electricien*, with the collaboration of engineers and industrial electricians. Vve. Ch. Dunod, publisher, Paris, 1902. Price of the entire collection, comprising some 15 numbers, 50 francs.

The twelfth number (eleventh in order of appearance) has just been issued. It is: ELECTRO-CHEMISTRY AND ELECTRO-METALLURGY, by André Brochet. 139 large pages, with 152 figures. A preface or introduction shows the installation of apparatus in various laboratories, principally on the continent of Europe Electrodes are here discussed at some length. Section I deals with the first half of the subject, and accords it extensive treatment Electrolysis of the various chlorine compounds receives a large amount of attention. Section II takes up the second half of the subject, paying particular attention to the methods employed for the reduction of copper, in the United States, and of gold in the Witwatersrand. Nickel, zinc and aluminum are also treated at length. A subscript or third section deals with ozone.

La Mécanique à l'Exposition de 1900. Published under the patronage and technical direction of a committee of editors, under the presidency of M. Haton de la Goupillière, inspector general of the mines. Vve. Ch. Dunod, publisher, Paris, 1902. Price of the entire collection, comprising some 20 numbers, 60 francs.

The fifth number (eleventh in order of appearance) has just been issued. It is entitled: *Hydraulic Motors*, by M. Rateau, Engineer of the Mines. 64 large pages, with 75 figures. As might be expected, the Swiss turbines come in for a very large amount of attention, the discussion of these machines occupying nearly one-half of the volume. Other makes represented were French, Austrian, Swedish and American. Of the latter, only the Sloan and the Cassel wheels are shown, though under the Swiss heading mention is made of the 5000 horse-power turbines of the Niagara Power Co., which are of Swiss design. The illustrations are clear, and splendidly supplement the reading of the text.

The ninth number (twelfth in order of appearance) has also been published. SAFETY APPLIANCES, by Henri Mamy, Engineer of Arts and Manufactures. 78 large pages, with 170 figures. Various forms of guards to prevent injury to persons using tools and machines are here shown and described, Among others may be mentioned guards for buzz-saws, tool-grinders, threshing-machine feeders, pulley-cones and clutches.

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